FIG. 1

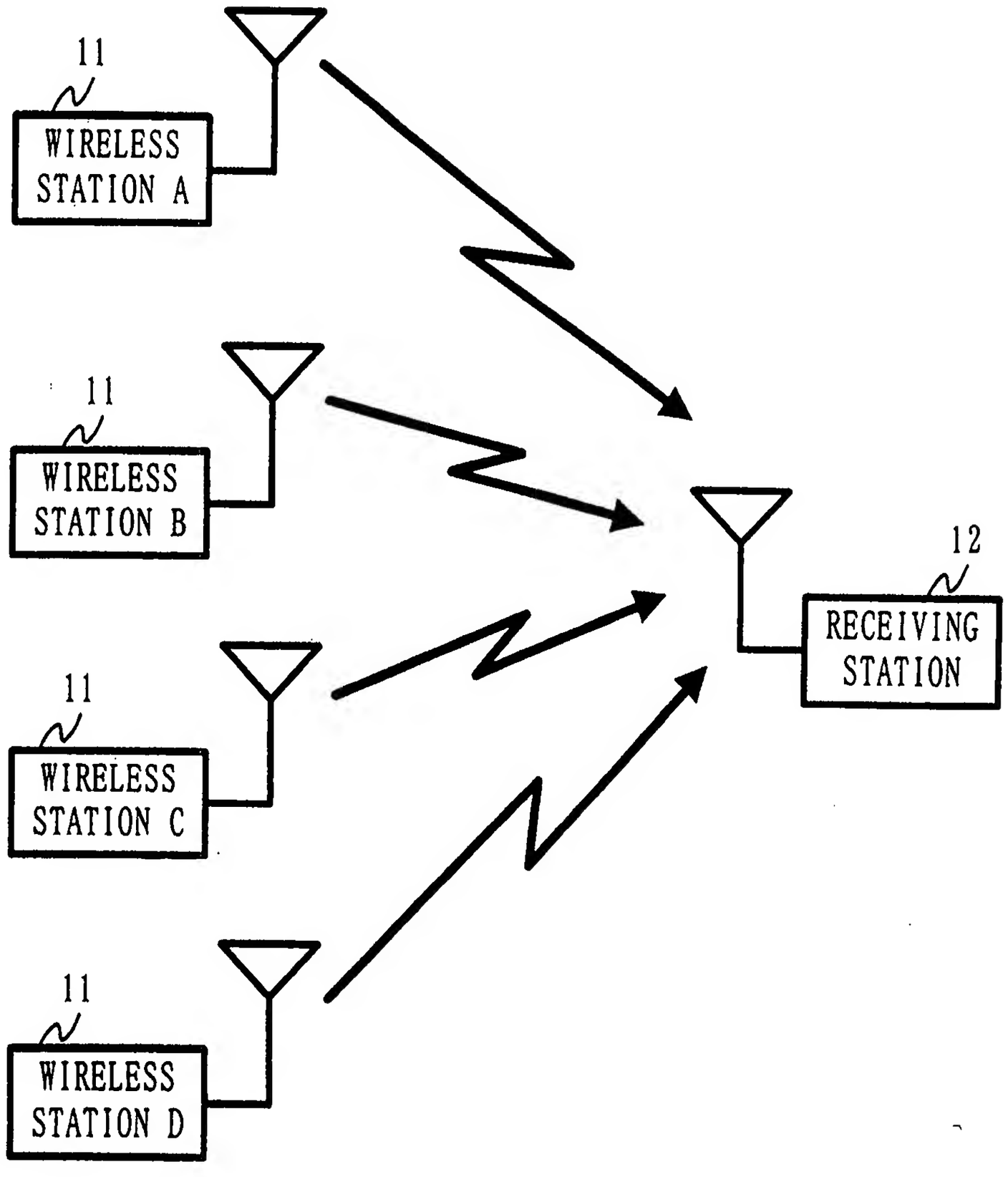

11
WIRELESS STATION A
11
WIRELESS STATION B
11
WIRELESS STATION C
11
WIRELESS STATION D
12
RECEIVING STATION

FIG. 2

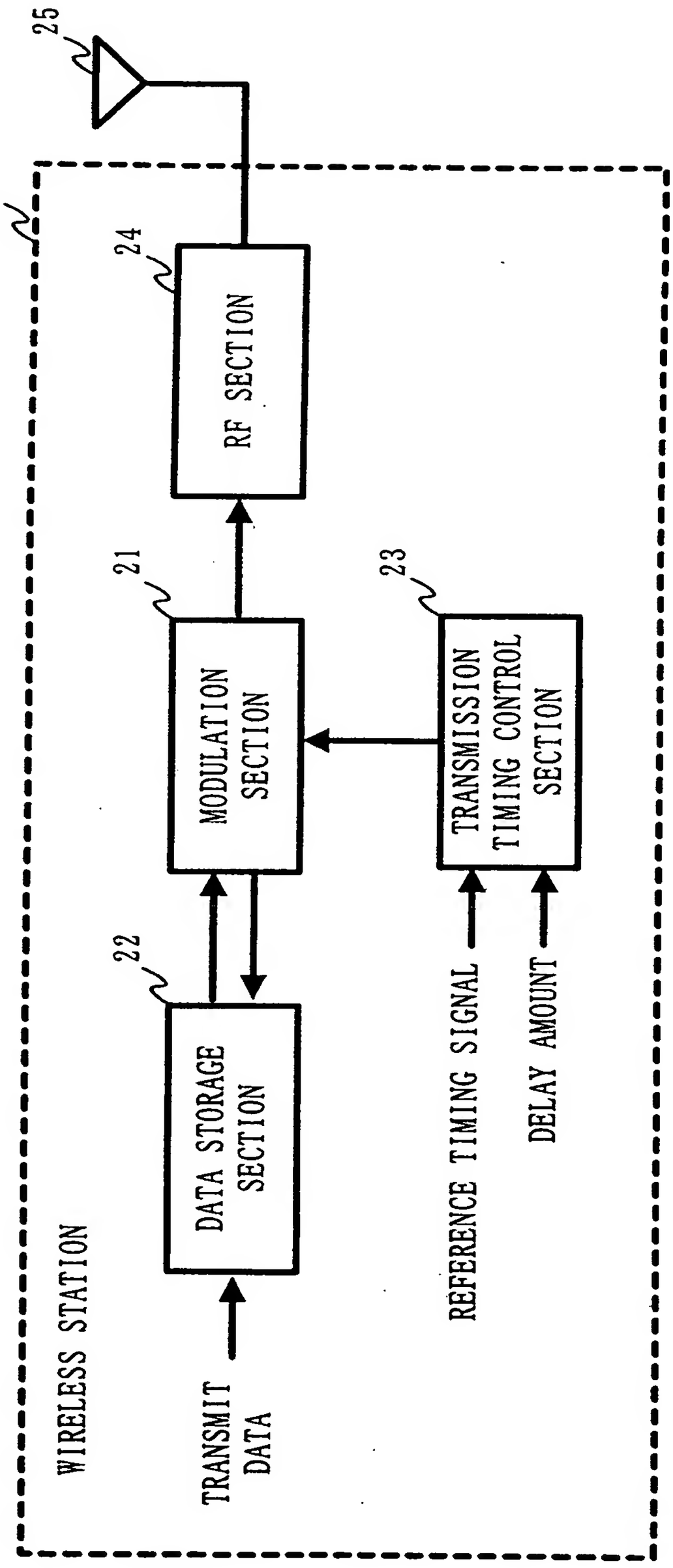

WIRELESS STATION
11
25
24
RF SECTION
21
MODULATION SECTION
22
DATA STORAGE SECTION
23
TRANSMISSION TIMING CONTROL SECTION
TRANSMIT DATA
TIMING SIGNAL
DELAY AMOUNT
REFERENCE TI

FIG. 3

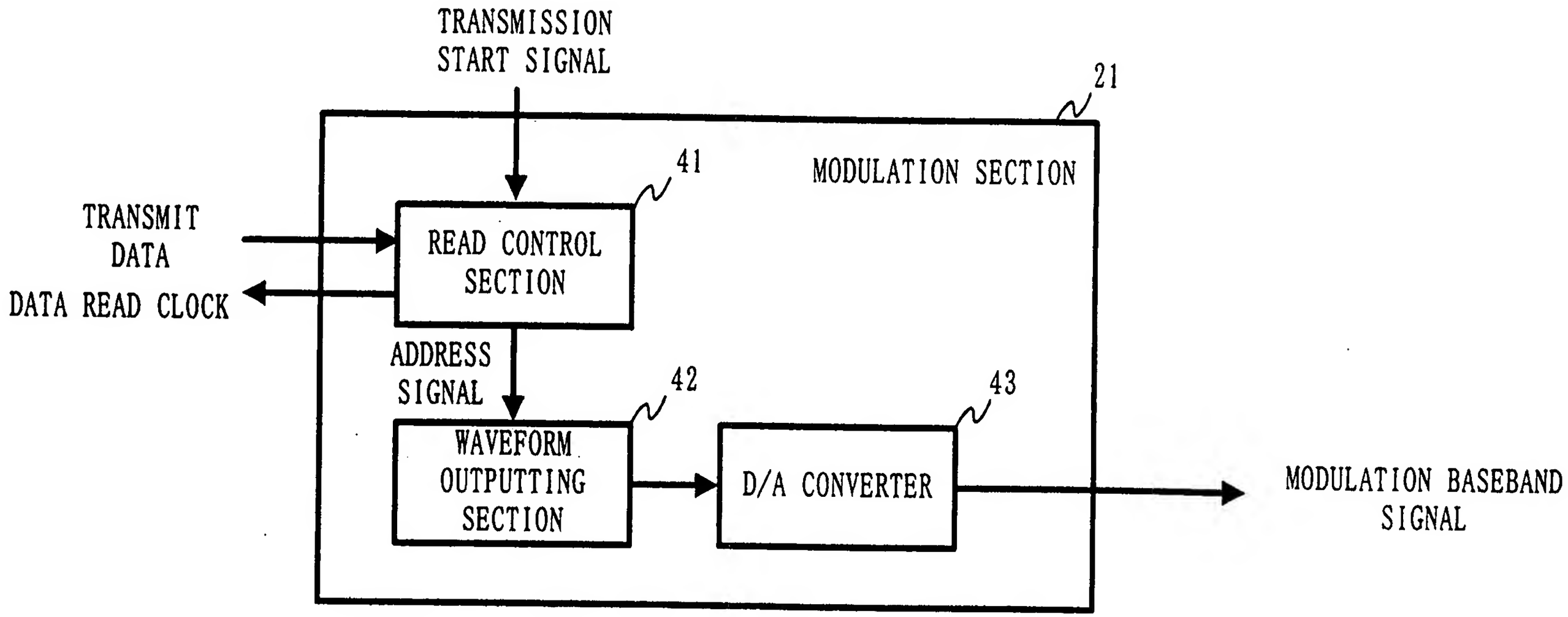

TRANSMISSION START SIGNAL
21
MODULATION SECTION
41
TRANSMIT DATA
DATA READ CLOCK
READ CONTROL SECTION
ADDRESS SIGNAL
42
WAVEFORM OUTPUTTING SECTION
43
D/A CONVERTER
MODULATION BASEBAND SIGNAL

FIG. 4

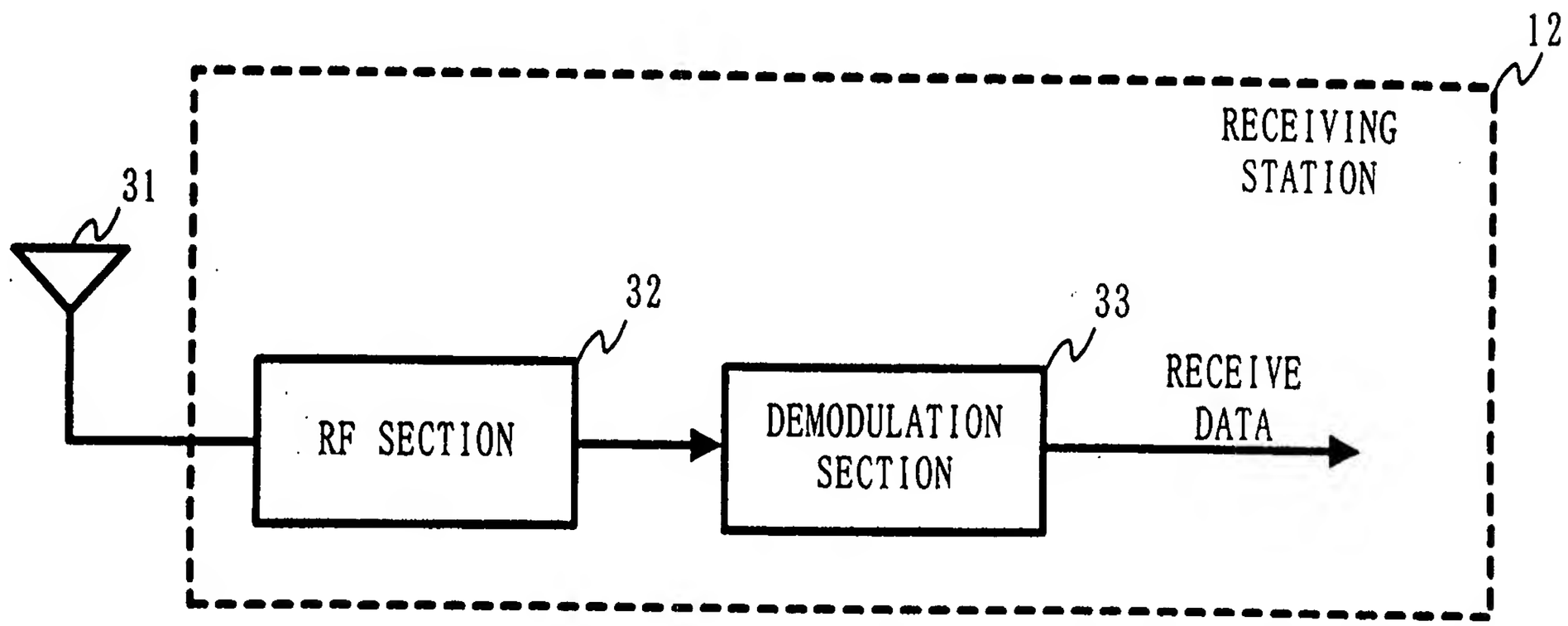

12
RECEIVING STATION
31
32
33
RF SECTION
DEMODULATION SECTION
RECEIVE DATA

FIG. 5

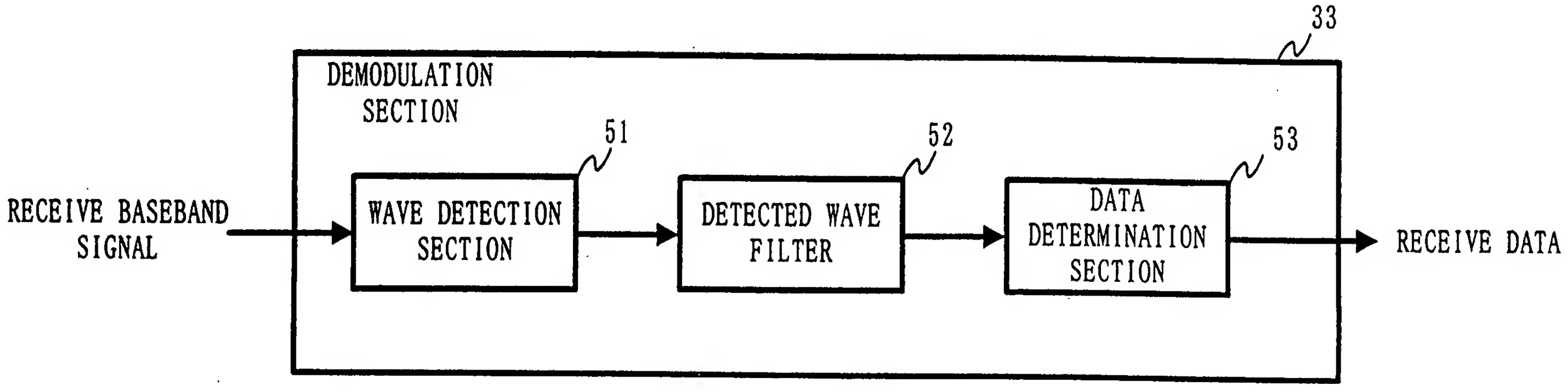

33
DEMODULATION SECTION
51
52
53
RECEIVE BASEBAND SIGNAL
WAVE DETECTION SECTION
DETECTED WAVE FILTER
DATA DETERMINATION SECTION
RECEIVE DATA

FIG. 6

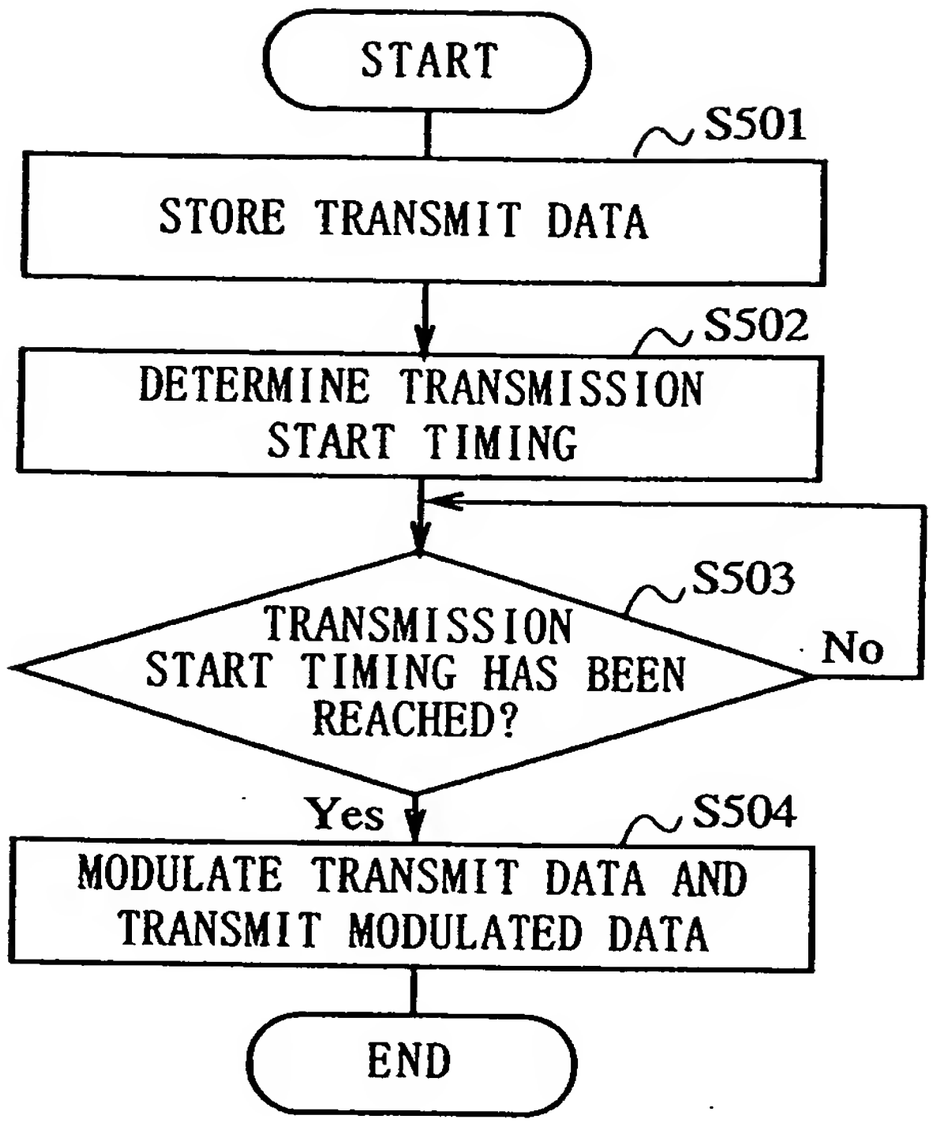

START
S501
STORE TRANSMIT DATA
S502
DETERMINE TRANSMISSION START TIMING
S503
TRANSMISSION START TIMING HAS BEEN REACHED?
No
Yes
S504
MODULATE TRANSMIT DATA AND TRANSMIT MODULATED DATA
END

FIG. 7

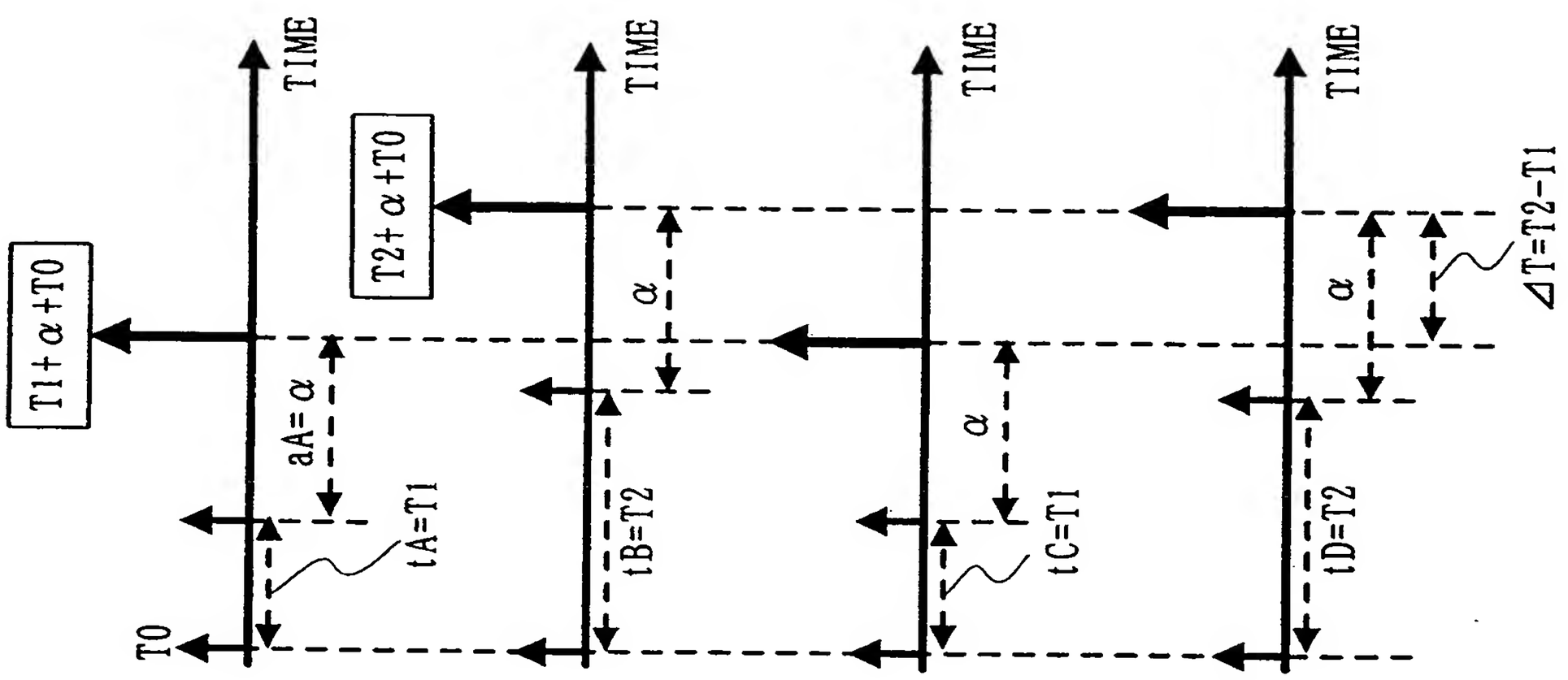

WIRELESS STATION A
WIRELESS STATION B
WIRELESS STATION C
WIRELESS STATION D
TIME
TIME
TIME
TIME
T1+α+T0
T2+α+T0
T0
aA=α
tA=T1
tB=T2
tC=T1
tD=T2
α
α
α
ΔT=T2-T1
PROPAGATION TIME LENGTH aA=aB=aC=aD =α

FIG. 8

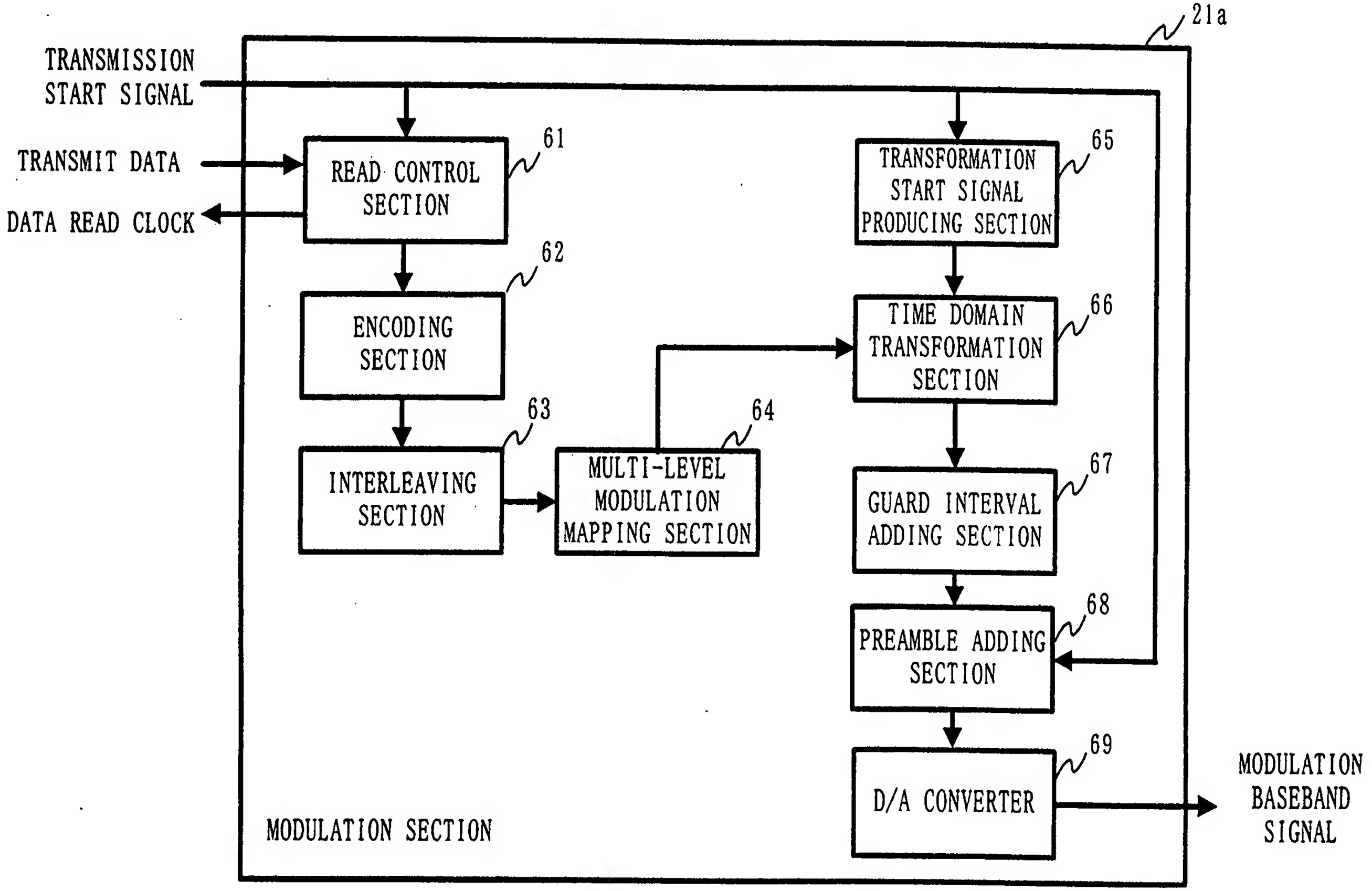
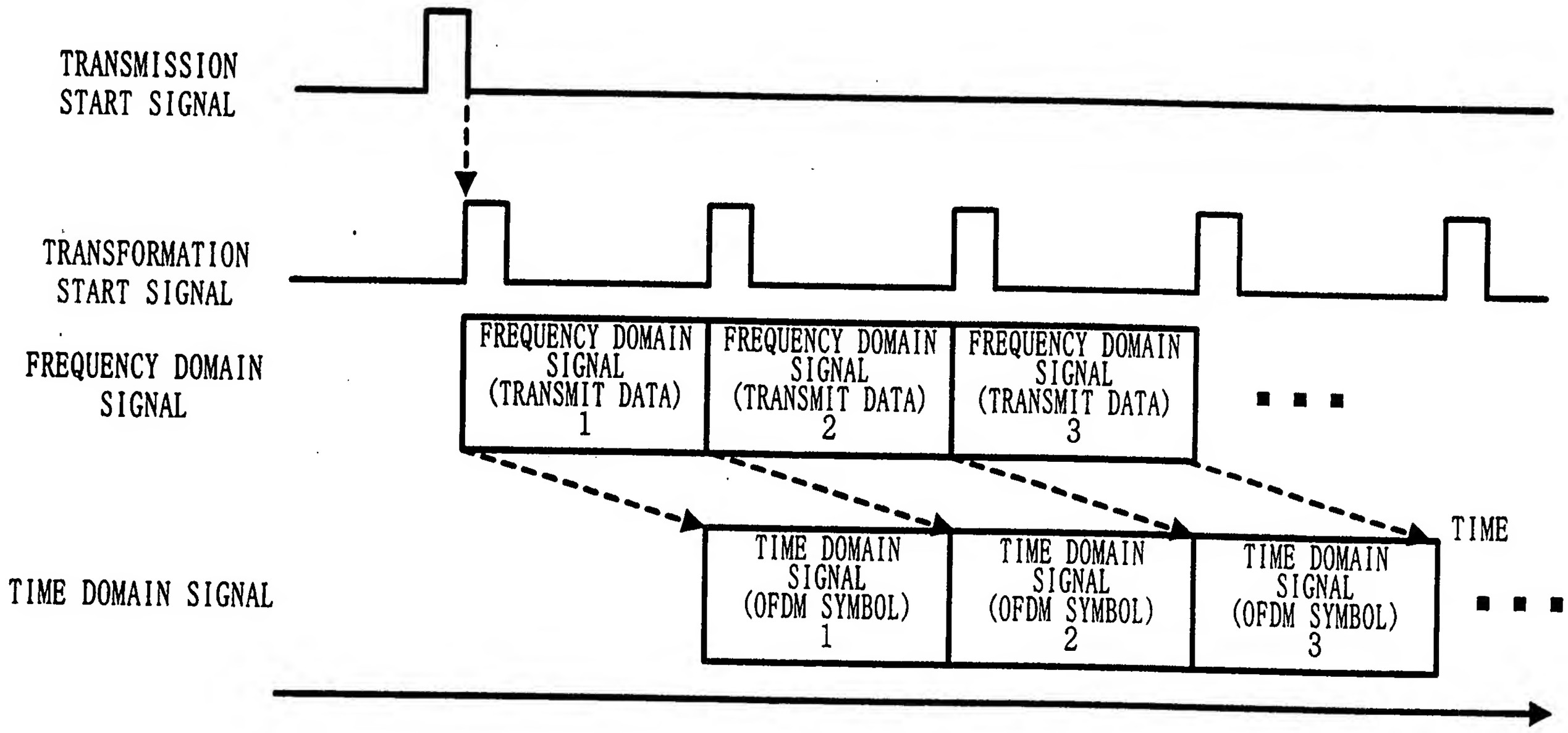

21a
TRANSMISSION START SIGNAL
TRANSMIT DATA
DATA READ CLOCK
READ CONTROL SECTION
61
ENCODING SECTION
62
INTERLEAVING SECTION
63
MULTI-LEVEL MODULATION MAPPING SECTION
64
TRANSFORMATION START SIGNAL PRODUCING SECTION
65
TIME DOMAIN TRANSFORMATION SECTION
66
GUARD INTERVAL ADDING SECTION
67
PREAMBLE ADDING SECTION
68
D/A CONVERTER
69
MODULATION BASEBAND SIGNAL
MODULATION SECTION

FIG. 9


TRANSMISSION START SIGNAL
TRANSFORMATION START SIGNAL
FREQUENCY DOMAIN SIGNAL
FREQUENCY DOMAIN SIGNAL (TRANSMIT DATA) 1
FREQUENCY DOMAIN SIGNAL (TRANSMIT DATA) 2
FREQUENCY DOMAIN SIGNAL (TRANSMIT DATA) 3
TIME DOMAIN SIGNAL
TIME DOMAIN SIGNAL (OFDM SYMBOL) 1
TIME DOMAIN SIGNAL (OFDM SYMBOL) 2
TIME DOMAIN SIGNAL (OFDM SYMBOL) 3
TIME

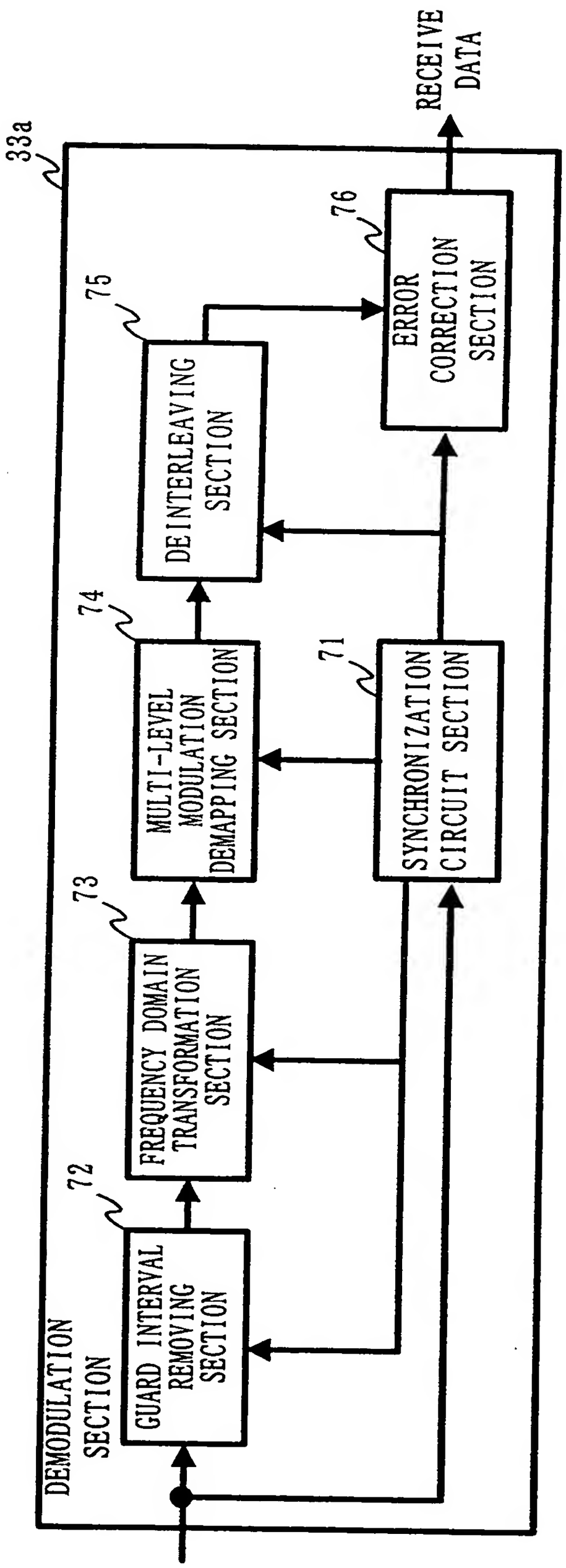

RECEIVE BASEBAND SIGNAL
DEMODULATION SECTION
GUARD INTERVAL REMOVING SECTION
72
FREQUENCY DOMAIN TRANSFORMATION SECTION
73
MULTI-LEVEL MODULATION DEMAPPING SECTION
74
DEINTERLEAVING SECTION
75
ERROR CORRECTION SECTION
76
SYNCHRONIZATION CIRCUIT SECTION
71
33a
RECEIVE DATA

FIG. 10

FIG. 11

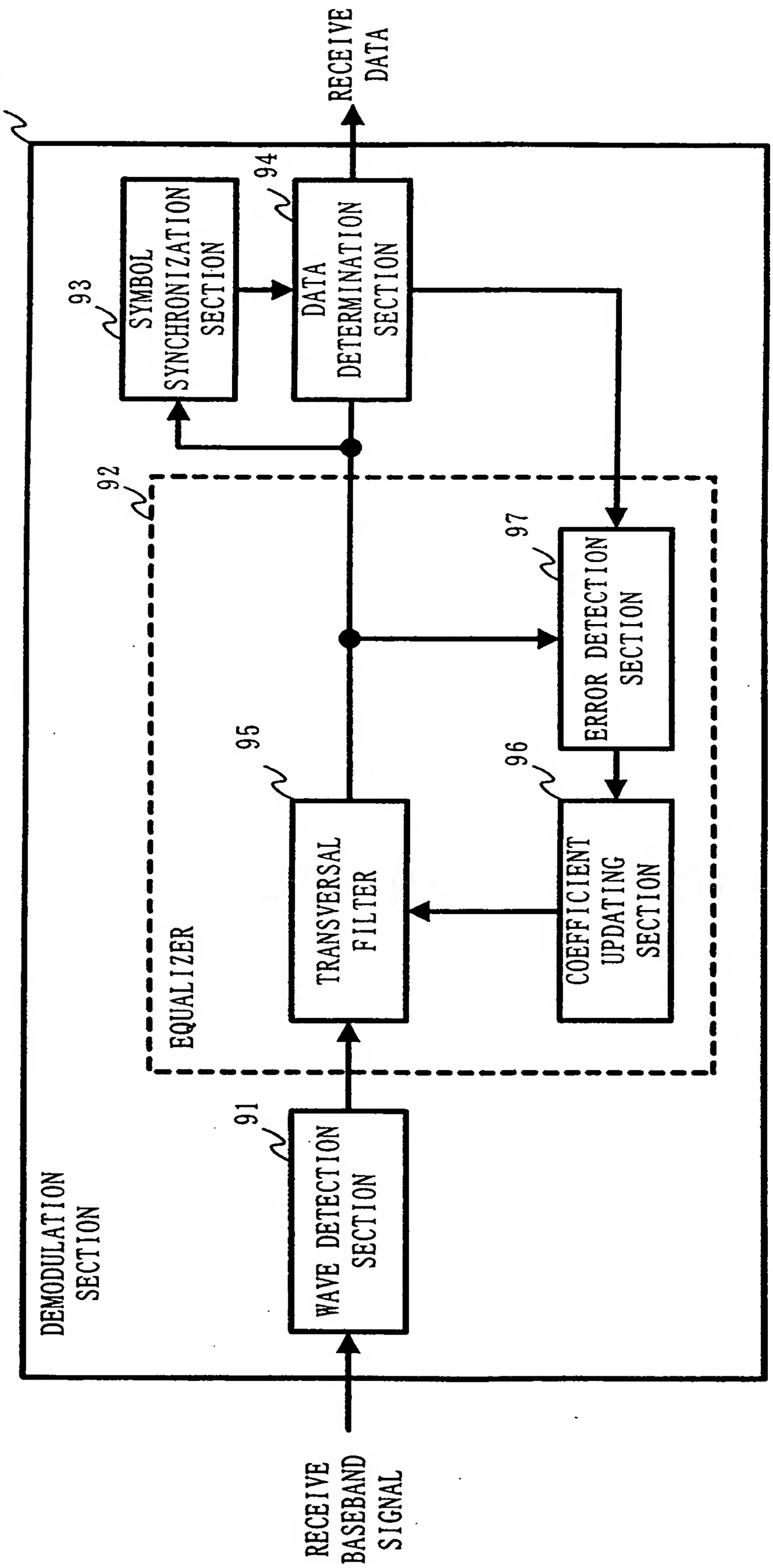

33b
RECEIVE DATA
94
DATA DETERMINATION SECTION
93
SYMBOL SYNCHRONIZATION SECTION
92
EQUALIZER
97
ERROR DETECTION SECTION
95
TRANSVERSAL FILTER
96
COEFFICIENT UPDATING SECTION
91
WAVE DETECTION SECTION
DEMODULATION SECTION
RECEIVE BASEBAND SIGNAL

FIG. 12

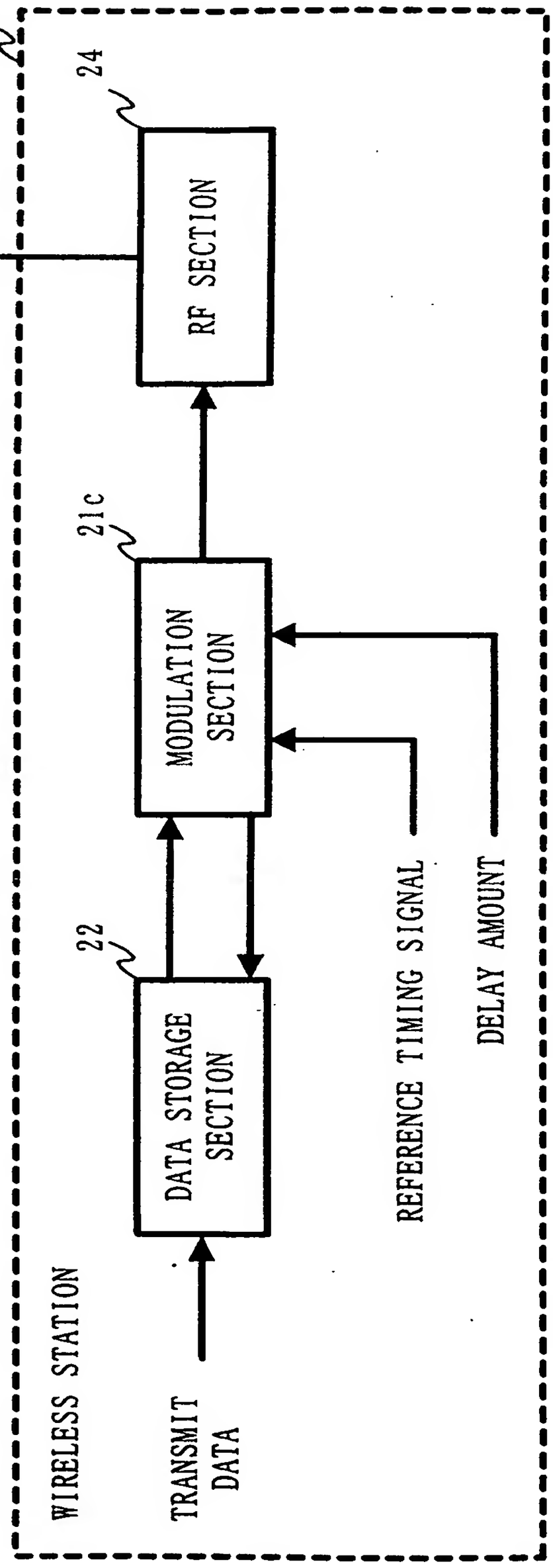

20
24
RF SECTION
25
21c
MODULATION SECTION
22
DATA STORAGE SECTION
REFERENCE TIMING SIGNAL
DELAY AMOUNT
WIRELESS STATION
TRANSMIT DATA

FIG. 13

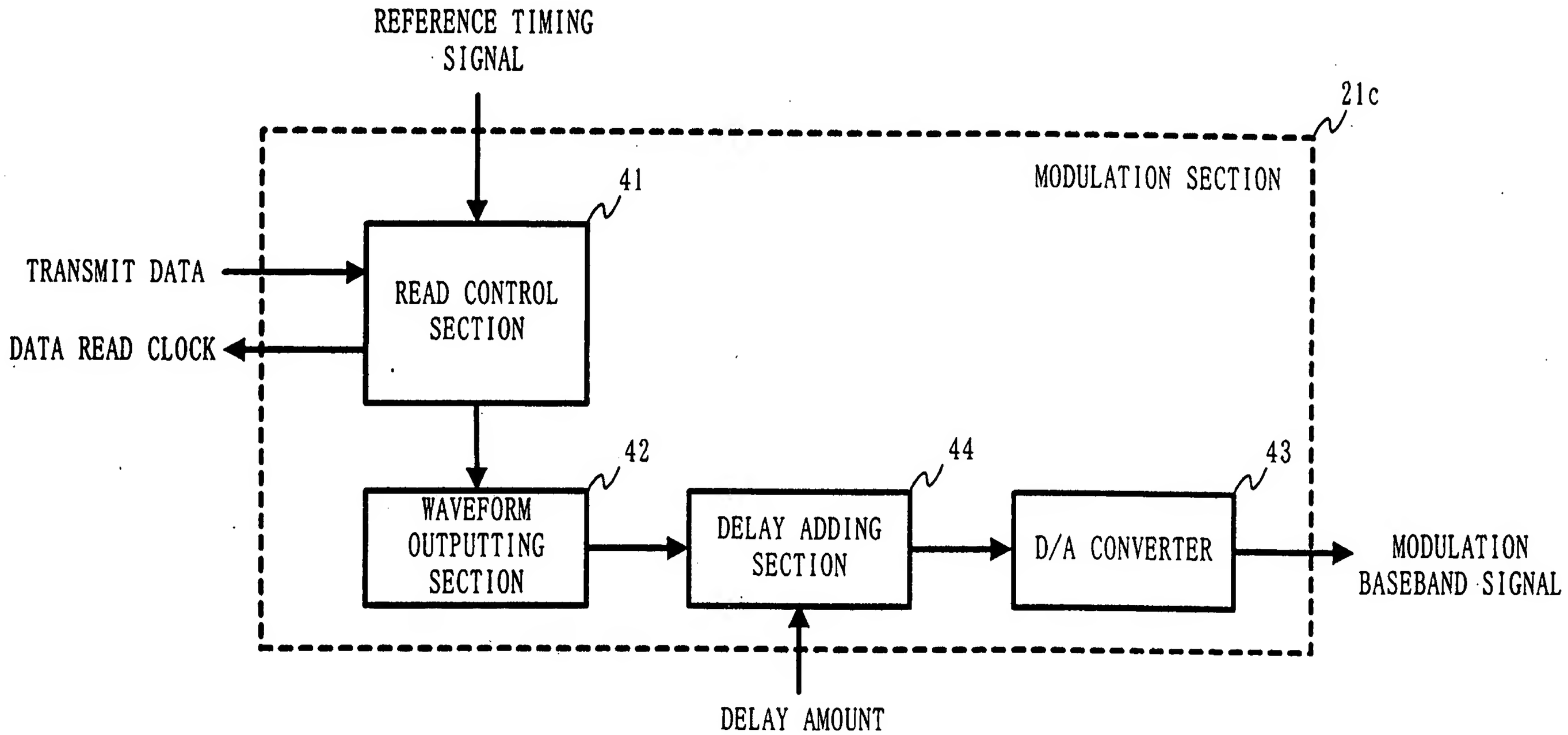

REFERENCE TIMING SIGNAL
21c
MODULATION SECTION
41
TRANSMIT DATA
READ CONTROL SECTION
DATA READ CLOCK
42
44
43
WAVEFORM OUTPUTTING SECTION
DELAY ADDING SECTION
D/A CONVERTER
MODULATION BASEBAND SIGNAL
DELAY AMOUNT

FIG. 14

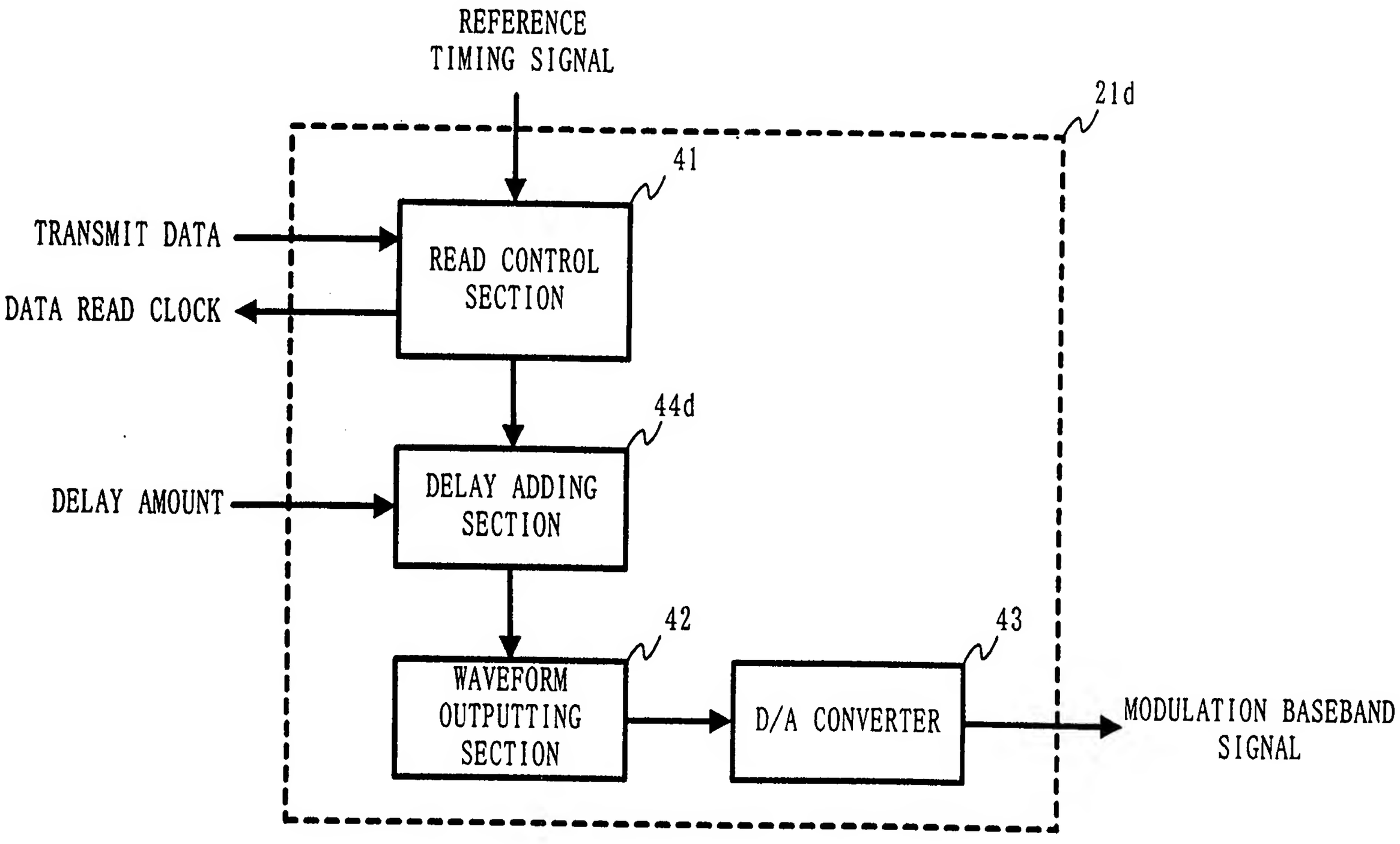
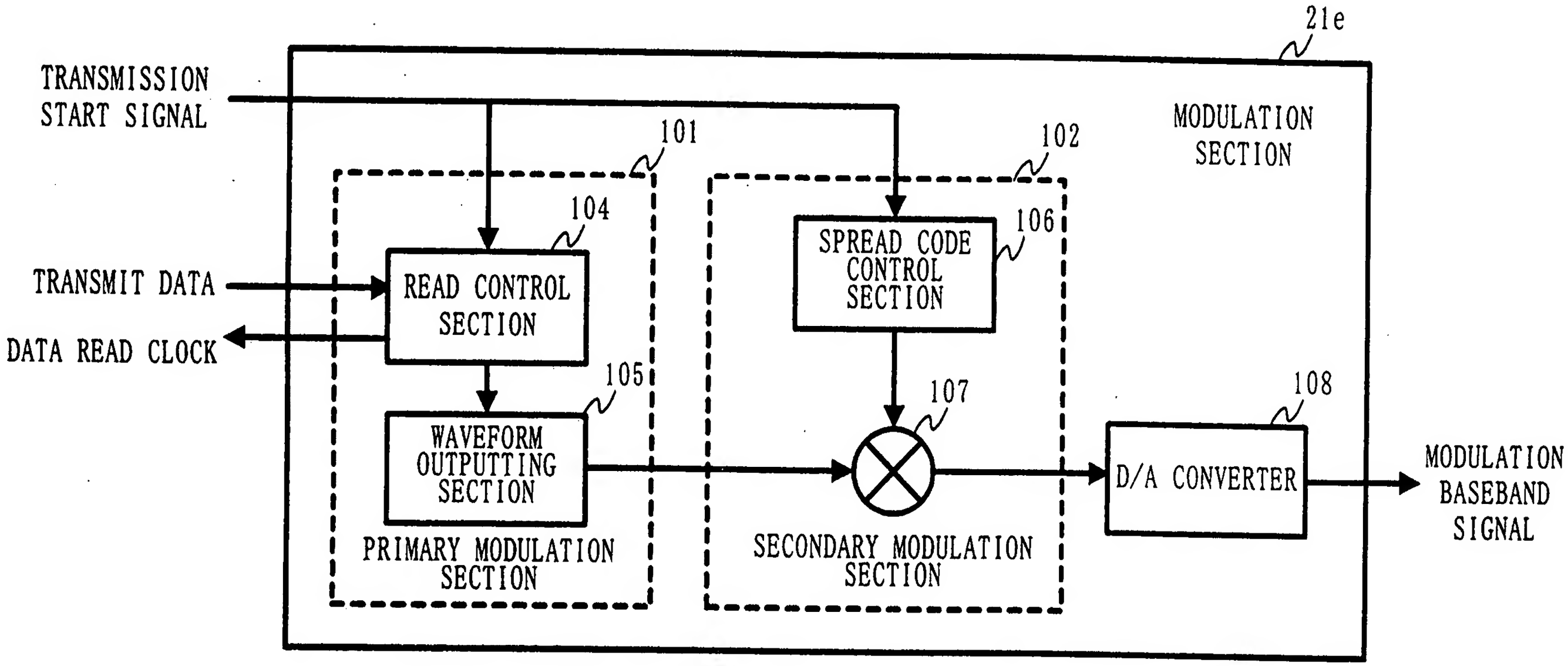

REFERENCE TIMING SIGNAL
21d
41
TRANSMIT DATA
DATA READ CLOCK
READ CONTROL SECTION
44d
DELAY AMOUNT
DELAY ADDING SECTION
42
43
WAVEFORM OUTPUTTING SECTION
D/A CONVERTER
MODULATION BASEBAND SIGNAL

FIG. 15


21e
TRANSMISSION START SIGNAL
MODULATION SECTION
101
102
104
106
TRANSMIT DATA
READ CONTROL SECTION
SPREAD CODE CONTROL SECTION
DATA READ CLOCK
105
107
108
WAVEFORM OUTPUTTING SECTION
D/A CONVERTER
MODULATION BASEBAND SIGNAL
PRIMARY MODULATION SECTION
SECONDARY MODULATION SECTION

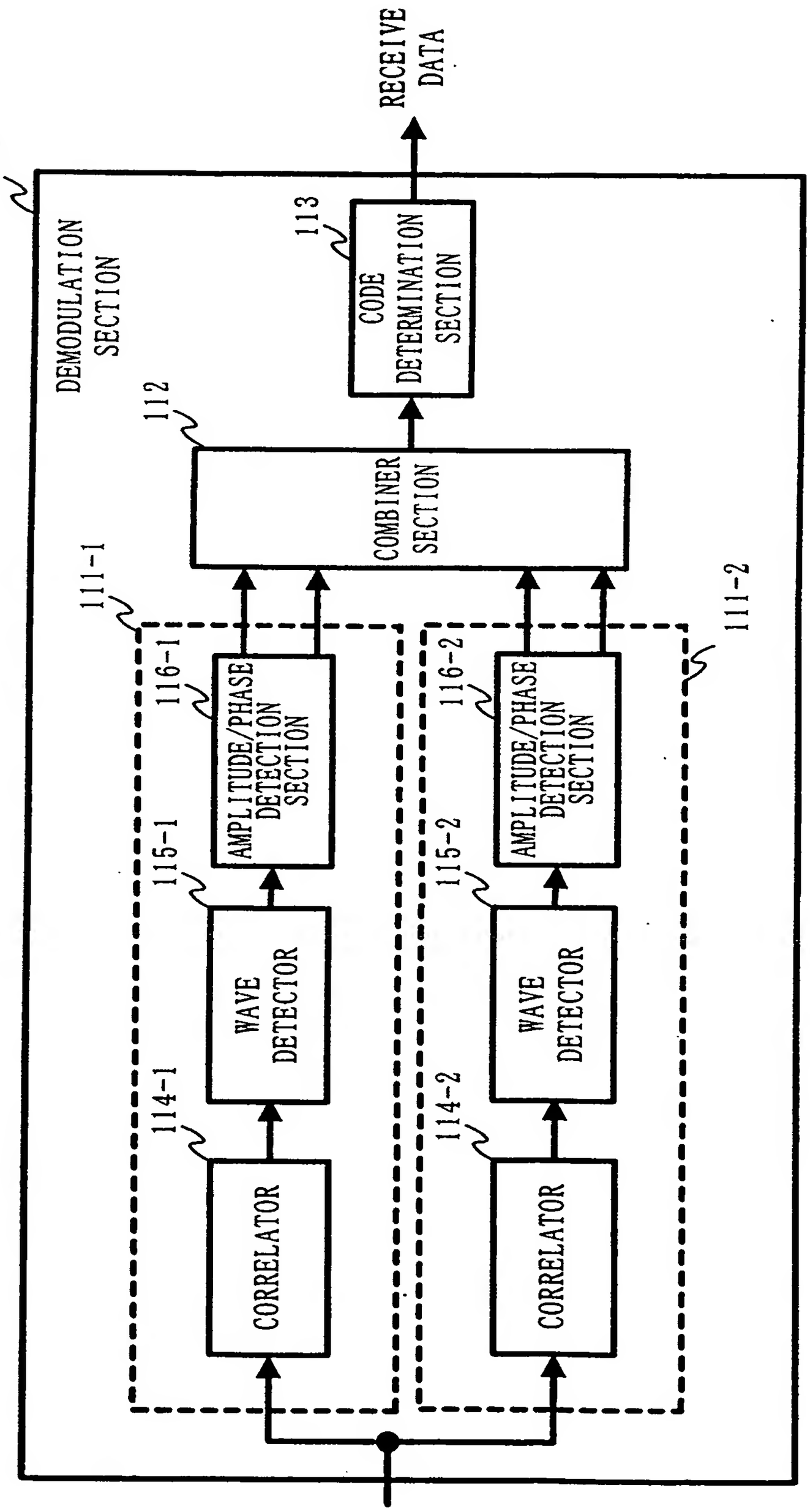

RECEIVE BASEBAND SIGNAL
33e
DEMODULATION SECTION
CORRELATOR
WAVE DETECTOR
AMPLITUDE/PHASE DETECTION SECTION
COMBINER SECTION
CODE DETERMINATION SECTION
RECEIVE DATA
114-1
114-2
115-1
115-2
116-1
116-2
111-1
111-2
112
113

FIG. 16

FIG. 17

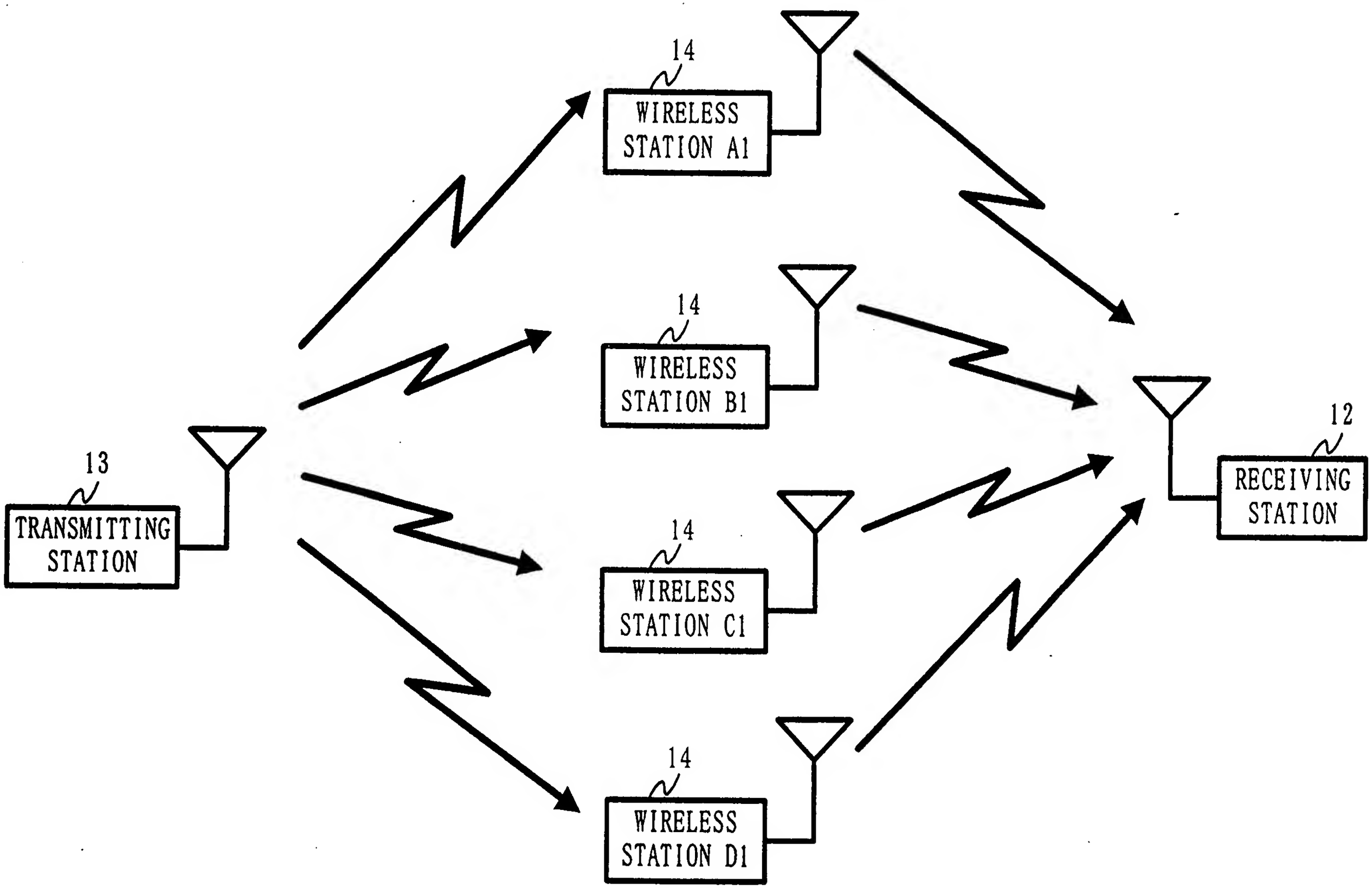

14
WIRELESS STATION A1
14
WIRELESS STATION B1
12
13
TRANSMITTING STATION
14
WIRELESS STATION C1
RECEIVING STATION
14
WIRELESS STATION D1

FIG. 18

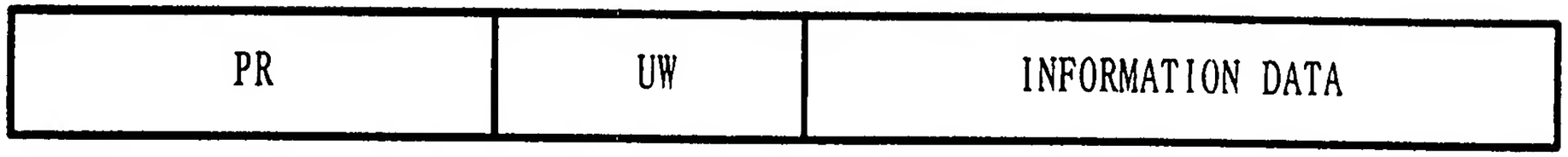

PR
UW
INFORMATION DATA

FIG. 19

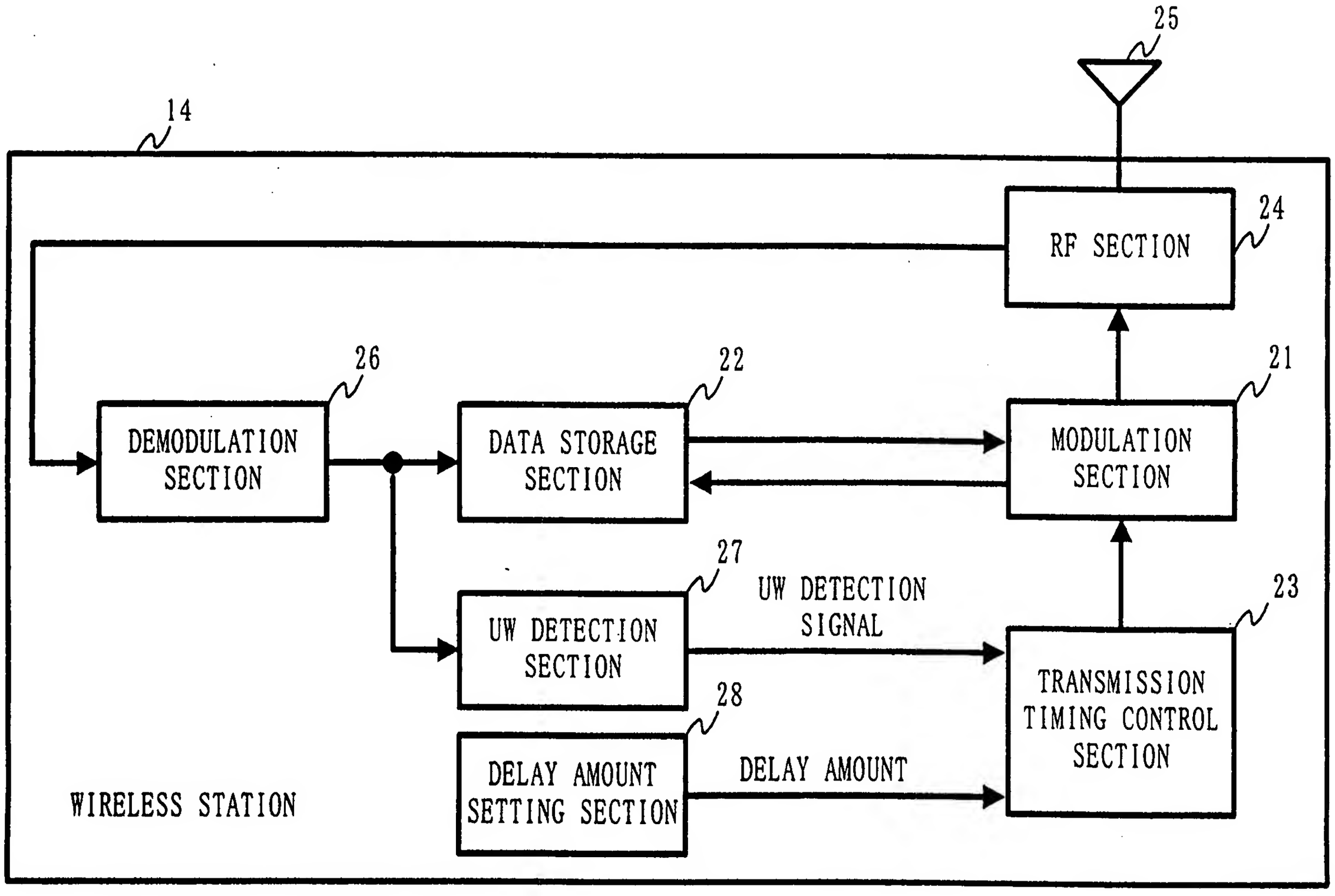

25
14
RF SECTION
24
26
DEMODULATION SECTION
22
DATA STORAGE SECTION
MODULATION SECTION
21
27
UW DETECTION SECTION
UW DETECTION SIGNAL
23
TRANSMISSION TIMING CONTROL SECTION
28
DELAY AMOUNT SETTING SECTION
DELAY AMOUNT
WIRELESS STATION

FIG. 20

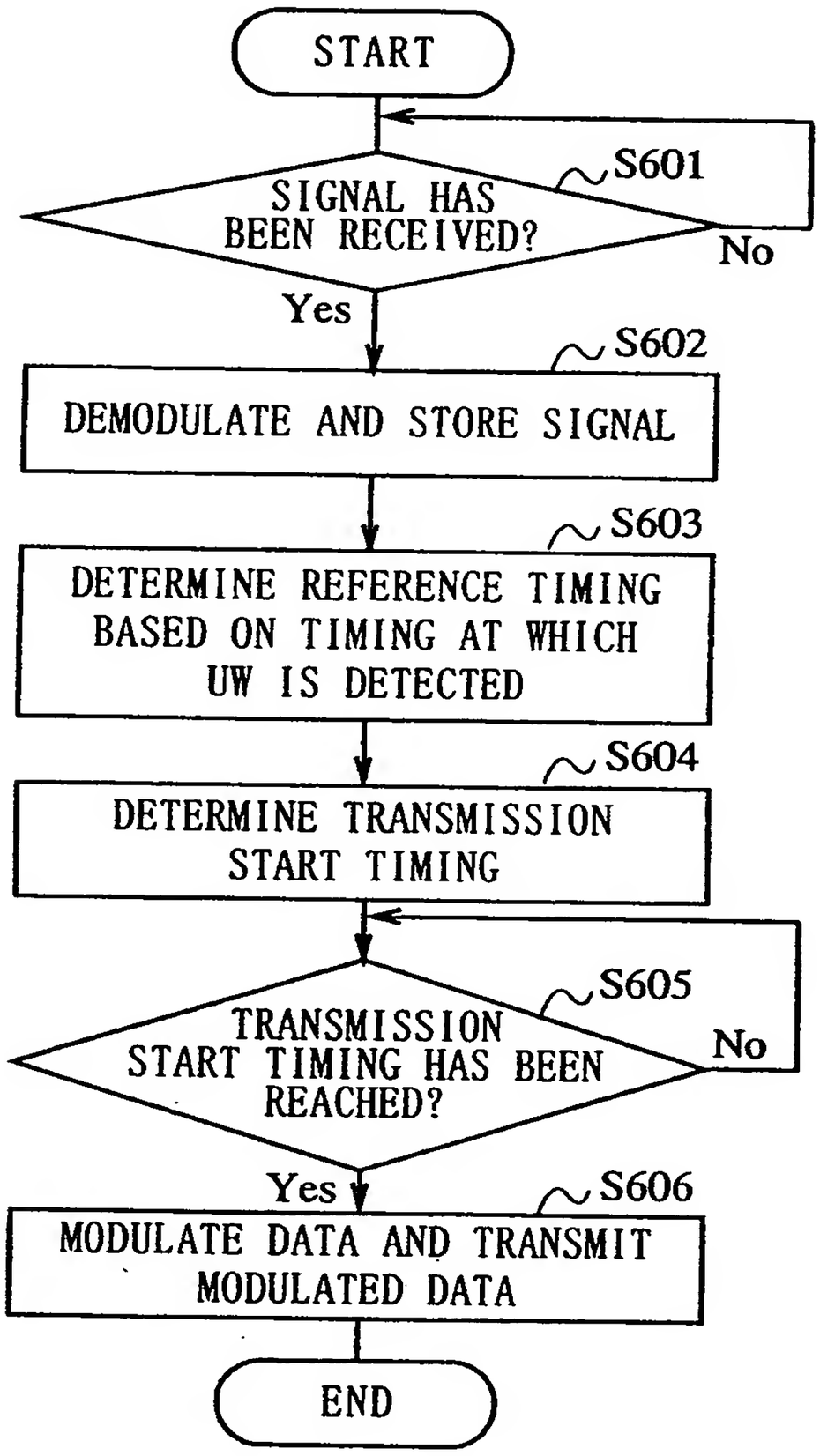

START
S601
SIGNAL HAS BEEN RECEIVED?
No
Yes
S602
DEMODULATE AND STORE SIGNAL
S603
DETERMINE REFERENCE TIMING BASED ON TIMING AT WHICH UW IS DETECTED
S604
DETERMINE TRANSMISSION START TIMING
S605
TRANSMISSION START TIMING HAS BEEN REACHED?
No
Yes
S606
MODULATE DATA AND TRANSMIT MODULATED DATA
END

FIG. 21

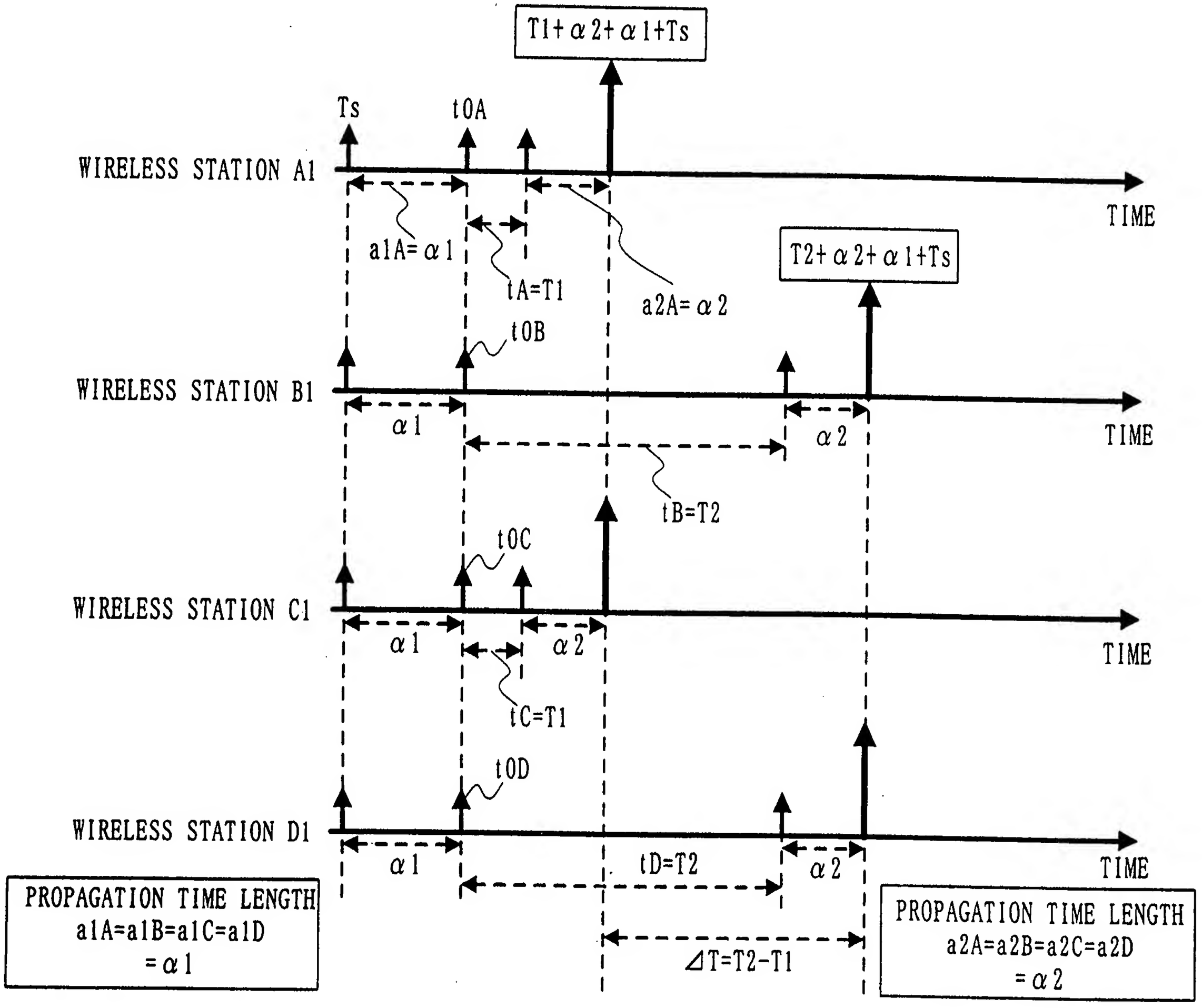

T1+α2+α1+Ts
Ts
t0A
WIRELESS STATION A1
TIME
a1A=α1
tA=T1
a2A=α2
T2+α2+α1+Ts
t0B
WIRELESS STATION B1
α1
α2
TIME
tB=T2
t0C
WIRELESS STATION C1
α1
α2
TIME
tC=T1
t0D
WIRELESS STATION D1
α1
tD=T2
α2
TIME
PROPAGATION TIME LENGTH
a1A=a1B=a1C=a1D
=α1
⊿T=T2-T1
PROPAGATION TIME LENGTH
a2A=a2B=a2C=a2D
=α2

FIG. 22

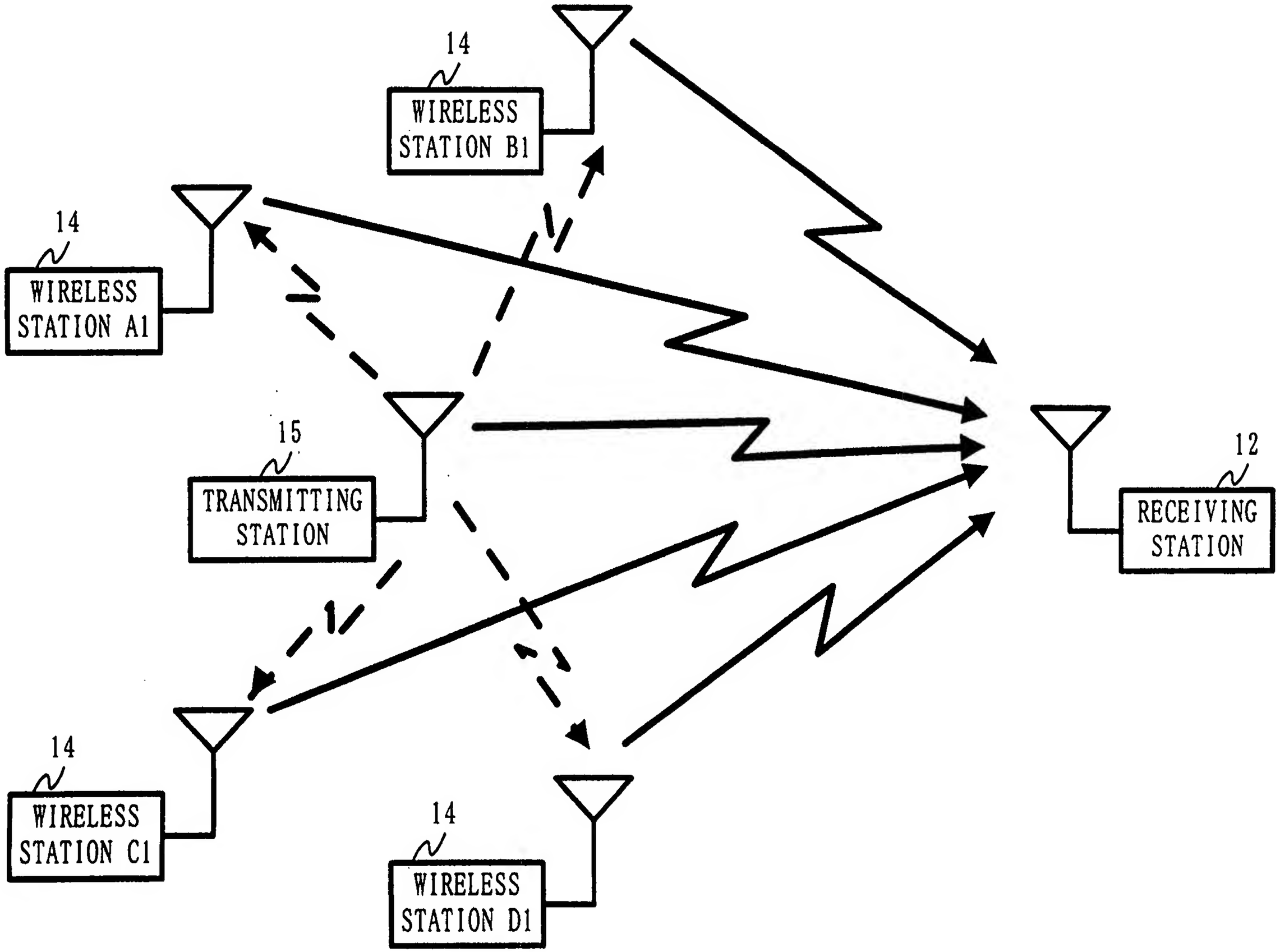

14
WIRELESS STATION B1
14
WIRELESS STATION A1
15
TRANSMITTING STATION
12
RECEIVING STATION
14
WIRELESS STATION C1
14
WIRELESS STATION D1

FIG. 23

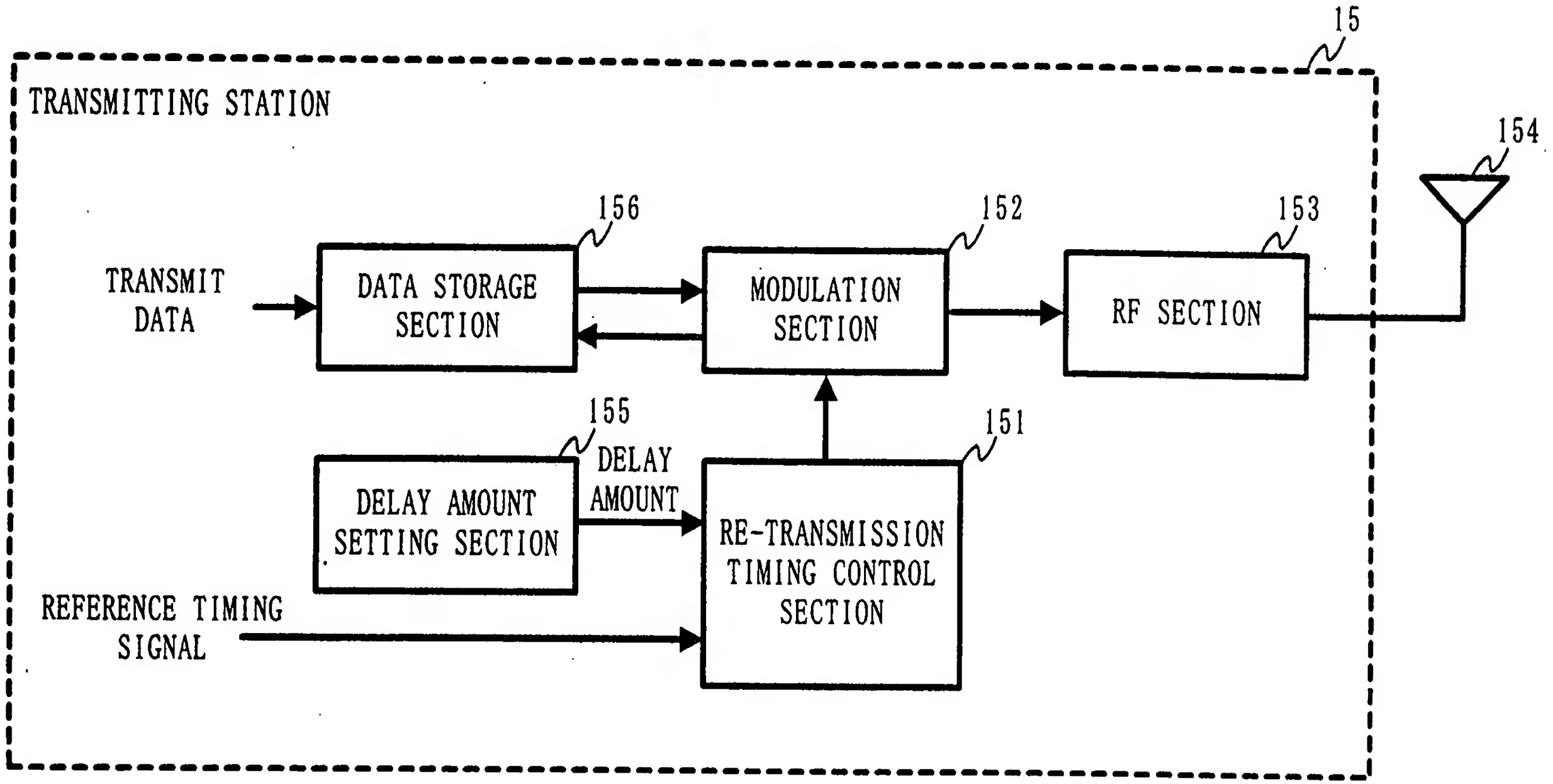

15
TRANSMITTING STATION
154
156
152
153
TRANSMIT DATA
DATA STORAGE SECTION
MODULATION SECTION
RF SECTION
155
151
DELAY AMOUNT SETTING SECTION
DELAY AMOUNT
RE-TRANSMISSION TIMING CONTROL SECTION
REFERENCE TIMING SIGNAL

FIG. 24

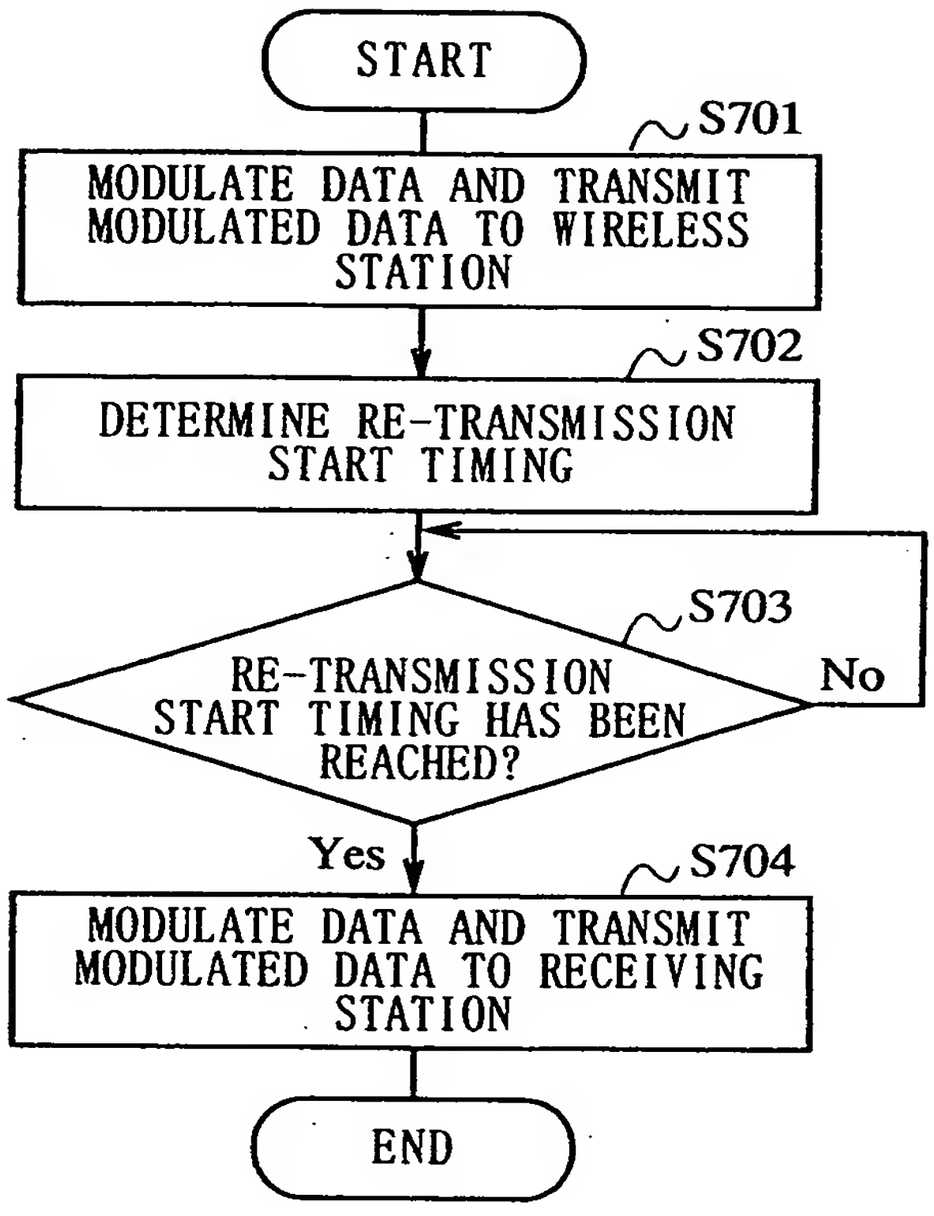

START
S701
MODULATE DATA AND TRANSMIT MODULATED DATA TO WIRELESS STATION
S702
DETERMINE RE-TRANSMISSION START TIMING
S703
RE-TRANSMISSION START TIMING HAS BEEN REACHED?
No
Yes
S704
MODULATE DATA AND TRANSMIT MODULATED DATA TO RECEIVING STATION
END

FIG. 25

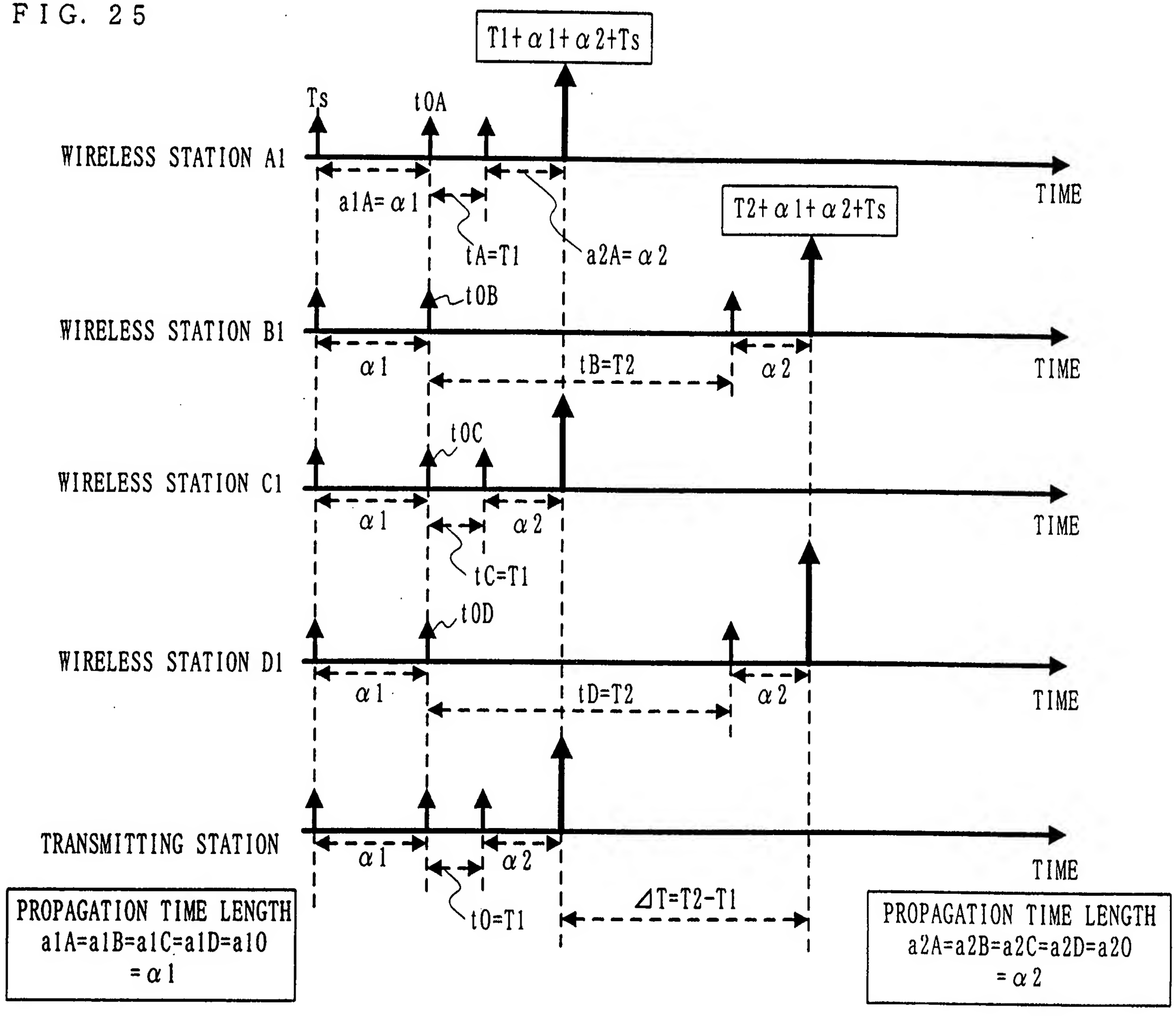

T1+α1+α2+Ts
Ts
tOA
WIRELESS STATION A1
TIME
a1A=α1
tA=T1
a2A=α2
T2+α1+α2+Ts
tOB
WIRELESS STATION B1
α1
tB=T2
α2
TIME
tOC
WIRELESS STATION C1
α1
α2
tC=T1
TIME
tOD
WIRELESS STATION D1
α1
tD=T2
α2
TIME
TRANSMITTING STATION
α1
α2
tO=T1
ΔT=T2-T1
TIME
PROPAGATION TIME LENGTH
a1A=a1B=a1C=a1D=a1O
=α1
PROPAGATION TIME LENGTH
a2A=a2B=a2C=a2D=a2O
=α2

FIG. 26

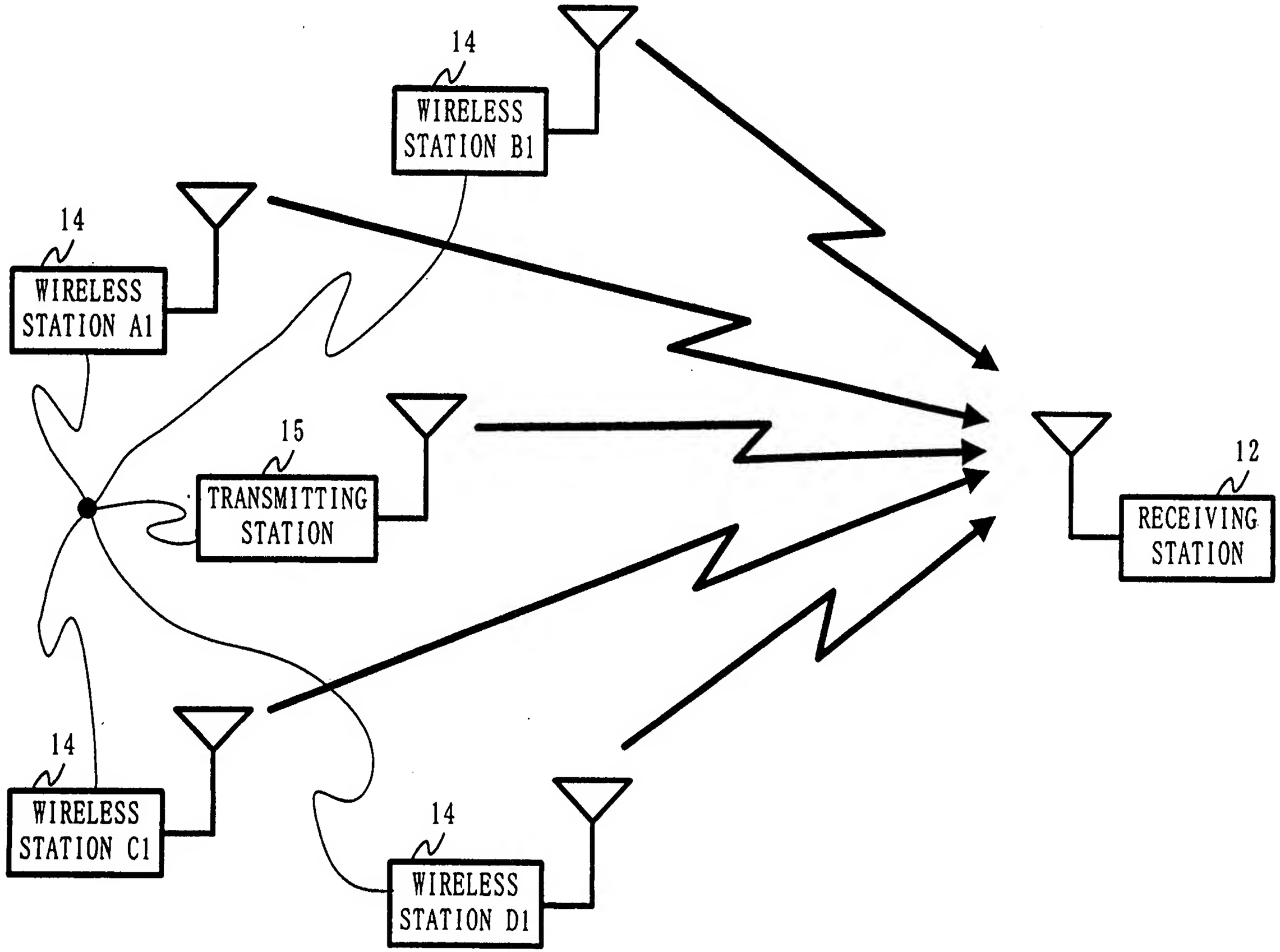
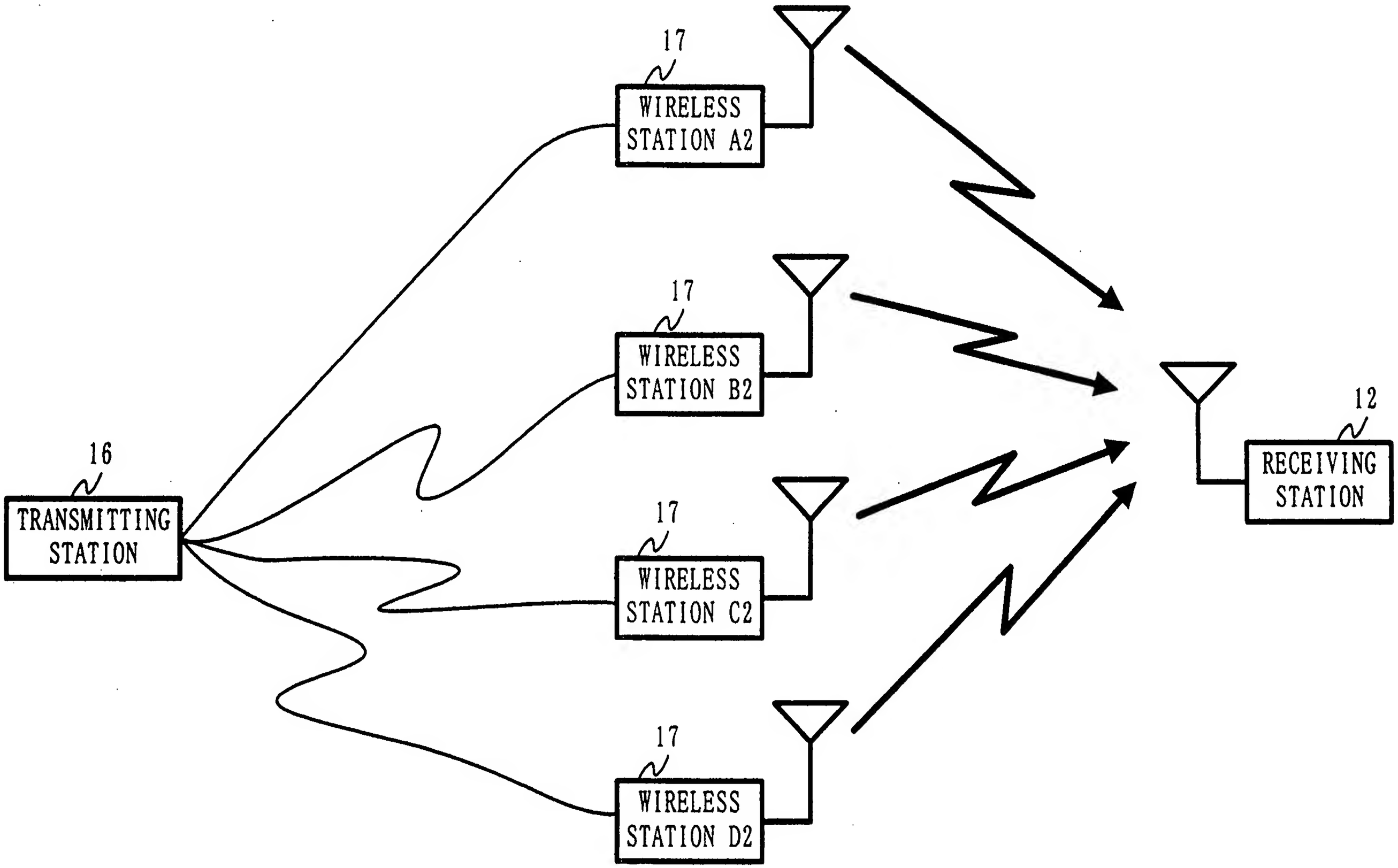

14
WIRELESS STATION B1
14
WIRELESS STATION A1
15
TRANSMITTING STATION
12
RECEIVING STATION
14
WIRELESS STATION C1
14
WIRELESS STATION D1

FIG. 27


17
WIRELESS STATION A2
17
WIRELESS STATION B2
12
RECEIVING STATION
16
TRANSMITTING STATION
17
WIRELESS STATION C2
17
WIRELESS STATION D2

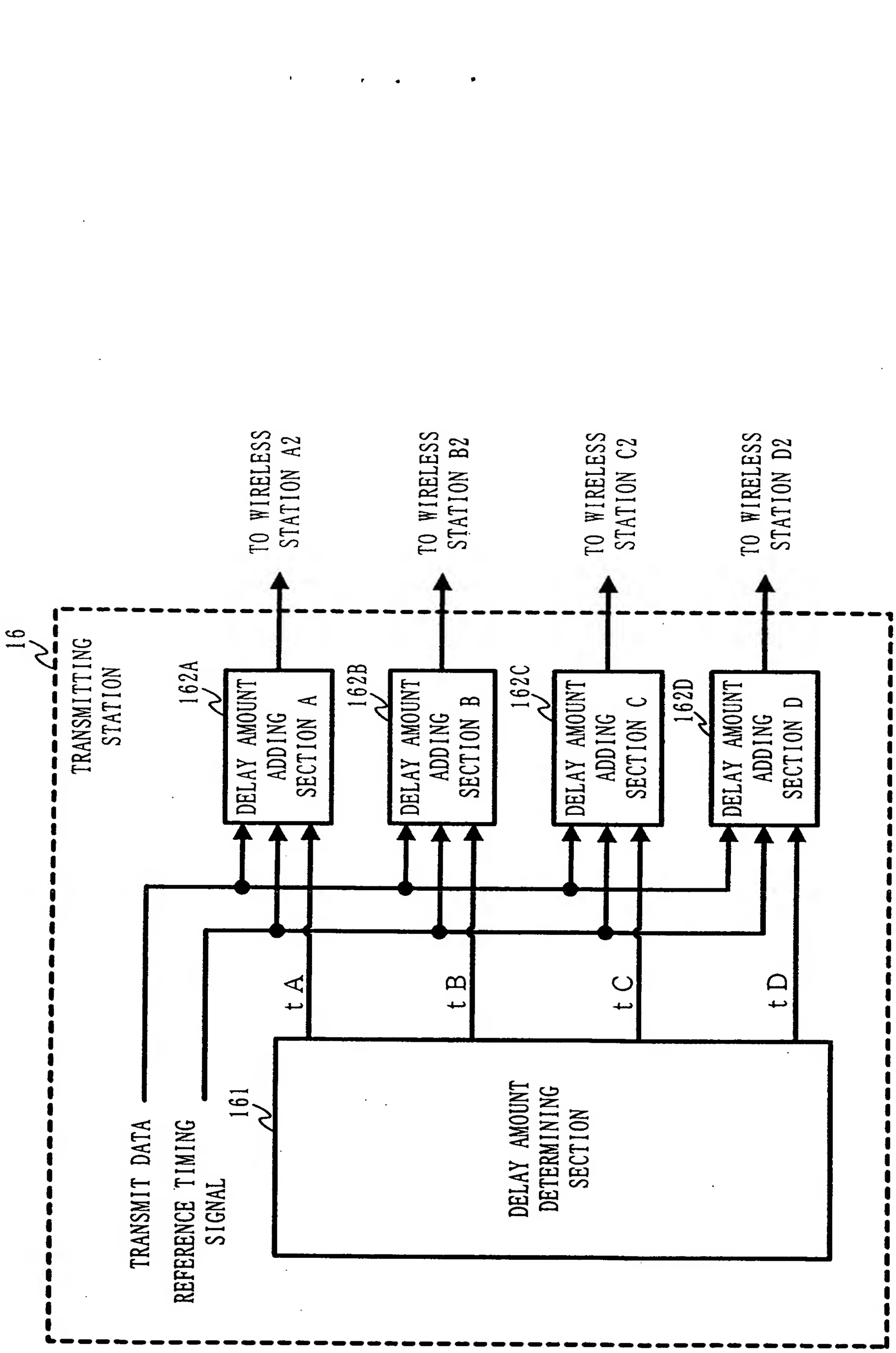

16
TRANSMITTING STATION
162A
DELAY AMOUNT ADDING SECTION A
162B
DELAY AMOUNT ADDING SECTION B
162C
DELAY AMOUNT ADDING SECTION C
162D
DELAY AMOUNT ADDING SECTION D
tA
tB
tC
tD
TRANSMIT DATA
REFERENCE TIMING SIGNAL
161
DELAY AMOUNT DETERMINING SECTION
TO WIRELESS STATION A2
TO WIRELESS STATION B2
TO WIRELESS STATION C2
TO WIRELESS STATION D2

FIG. 28

FIG. 29

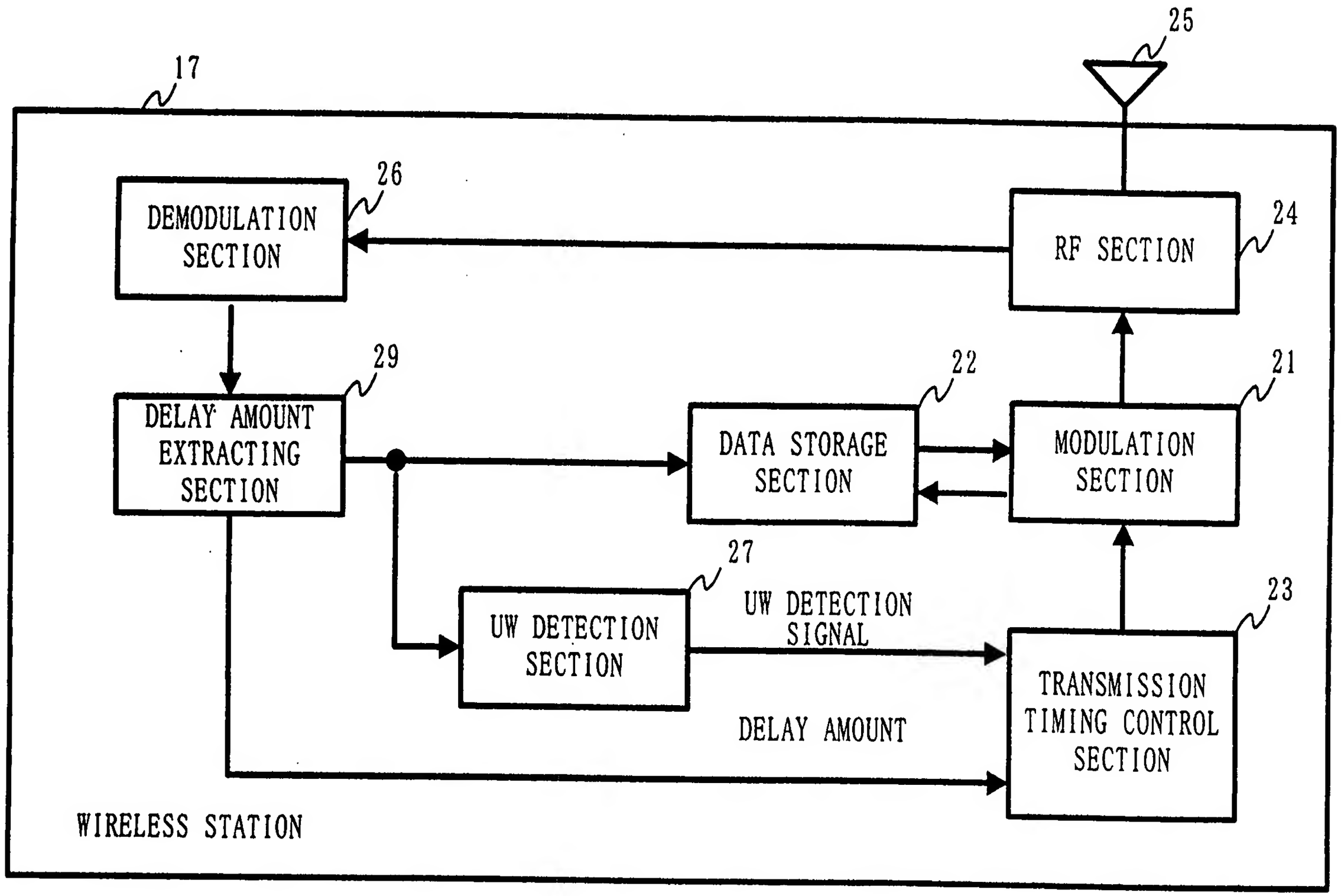

17
25
26
DEMODULATION SECTION
RF SECTION
24
29
22
21
DELAY AMOUNT EXTRACTING SECTION
DATA STORAGE SECTION
MODULATION SECTION
27
UW DETECTION SECTION
UW DETECTION SIGNAL
23
TRANSMISSION TIMING CONTROL SECTION
DELAY AMOUNT
WIRELESS STATION

FIG. 30

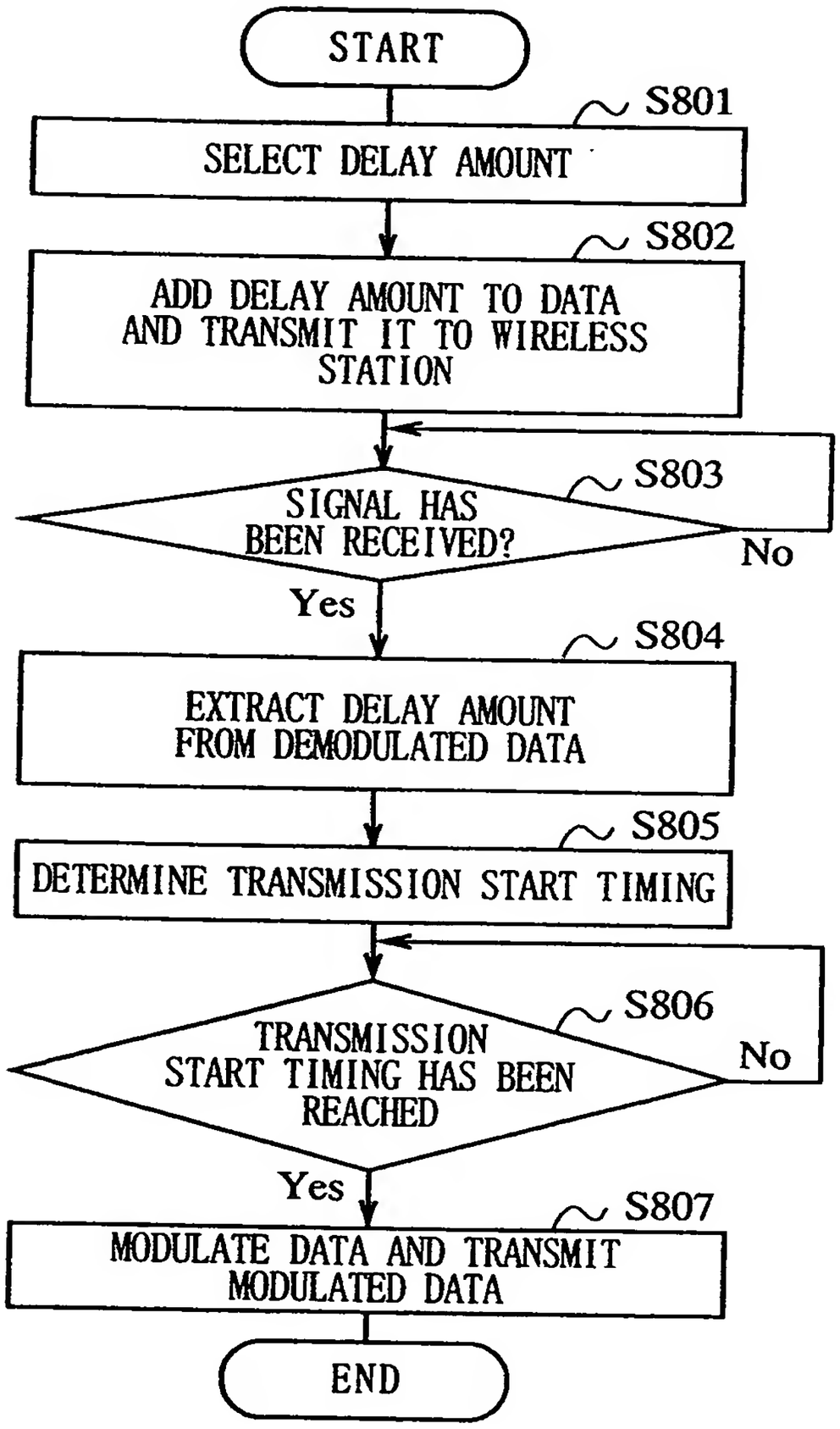

START
S801
SELECT DELAY AMOUNT
S802
ADD DELAY AMOUNT TO DATA AND TRANSMIT IT TO WIRELESS STATION
S803
SIGNAL HAS BEEN RECEIVED?
No
Yes
S804
EXTRACT DELAY AMOUNT FROM DEMODULATED DATA
S805
DETERMINE TRANSMISSION START TIMING
S806
TRANSMISSION START TIMING HAS BEEN REACHED
No
Yes
S807
MODULATE DATA AND TRANSMIT MODULATED DATA
END

FIG. 31

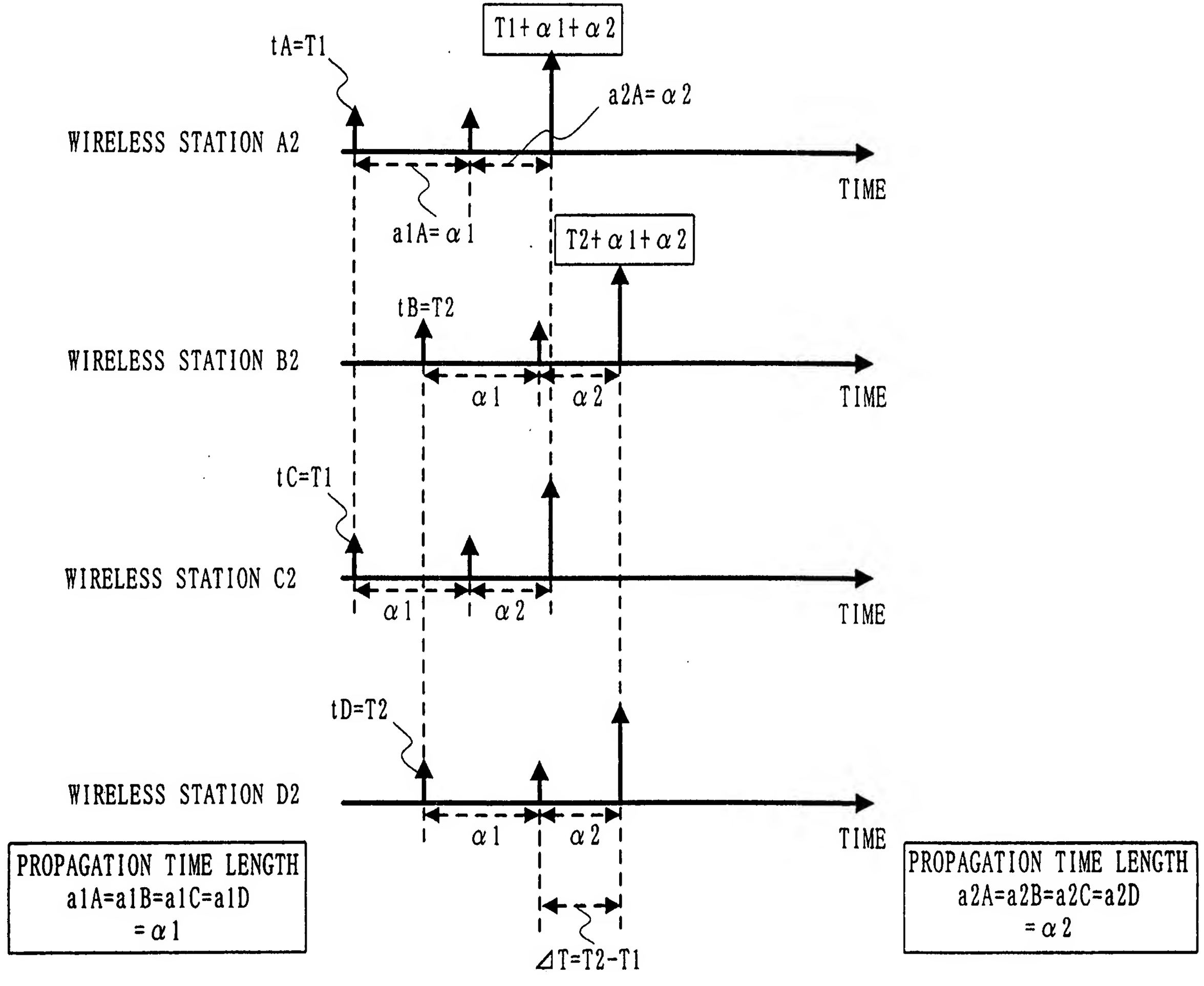

tA=T1
T1+α1+α2
a2A=α2
WIRELESS STATION A2
TIME
a1A=α1
T2+α1+α2
tB=T2
WIRELESS STATION B2
α1
α2
TIME
tC=T1
WIRELESS STATION C2
α1
α2
TIME
tD=T2
WIRELESS STATION D2
α1
α2
TIME
ΔT=T2-T1
PROPAGATION TIME LENGTH
a1A=a1B=a1C=a1D
=α1
PROPAGATION TIME LENGTH
a2A=a2B=a2C=a2D
=α2

FIG. 32

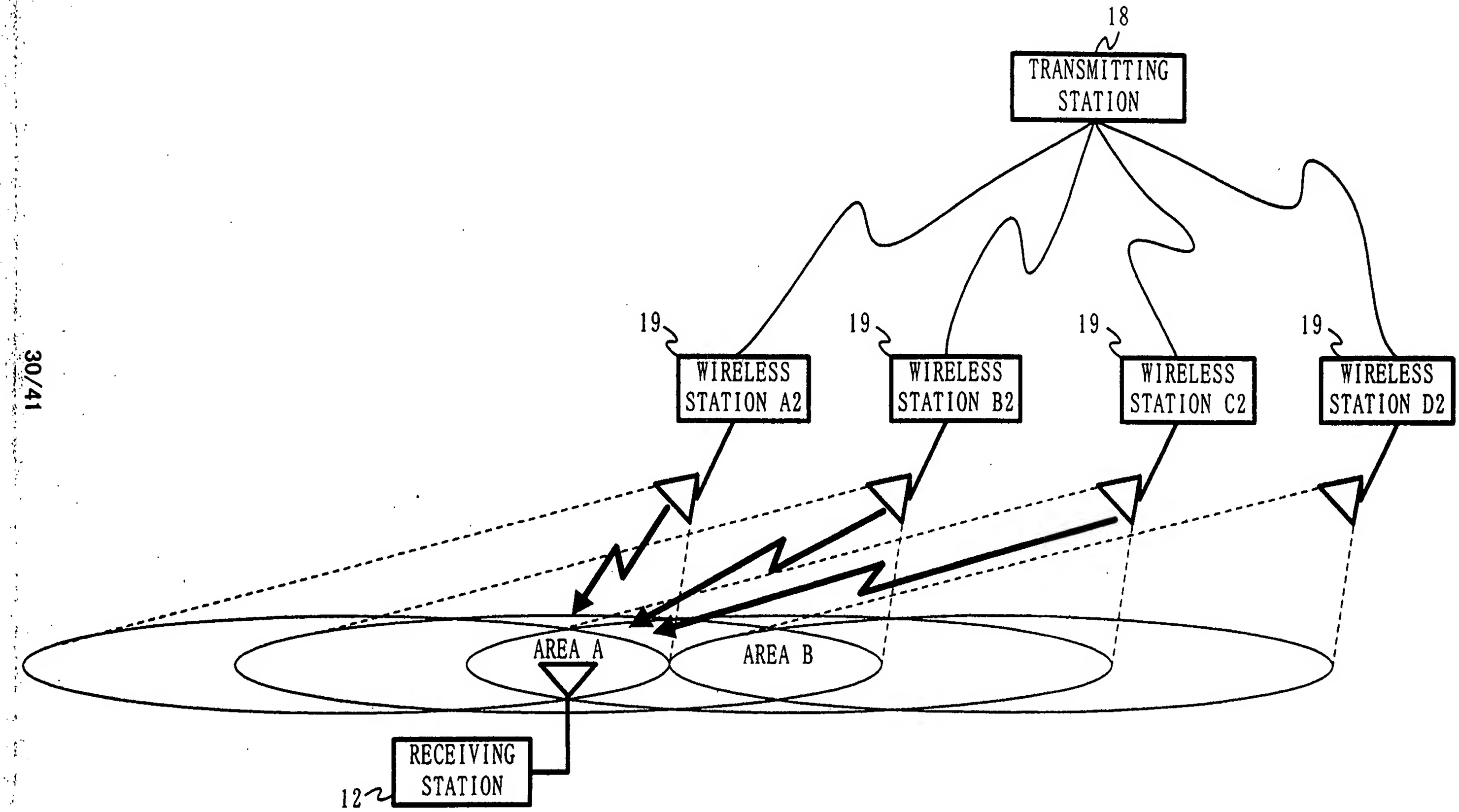

18
TRANSMITTING STATION
19
WIRELESS STATION A2
19
WIRELESS STATION B2
19
WIRELESS STATION C2
19
WIRELESS STATION D2
AREA A
AREA B
RECEIVING STATION
12

FIG. 33

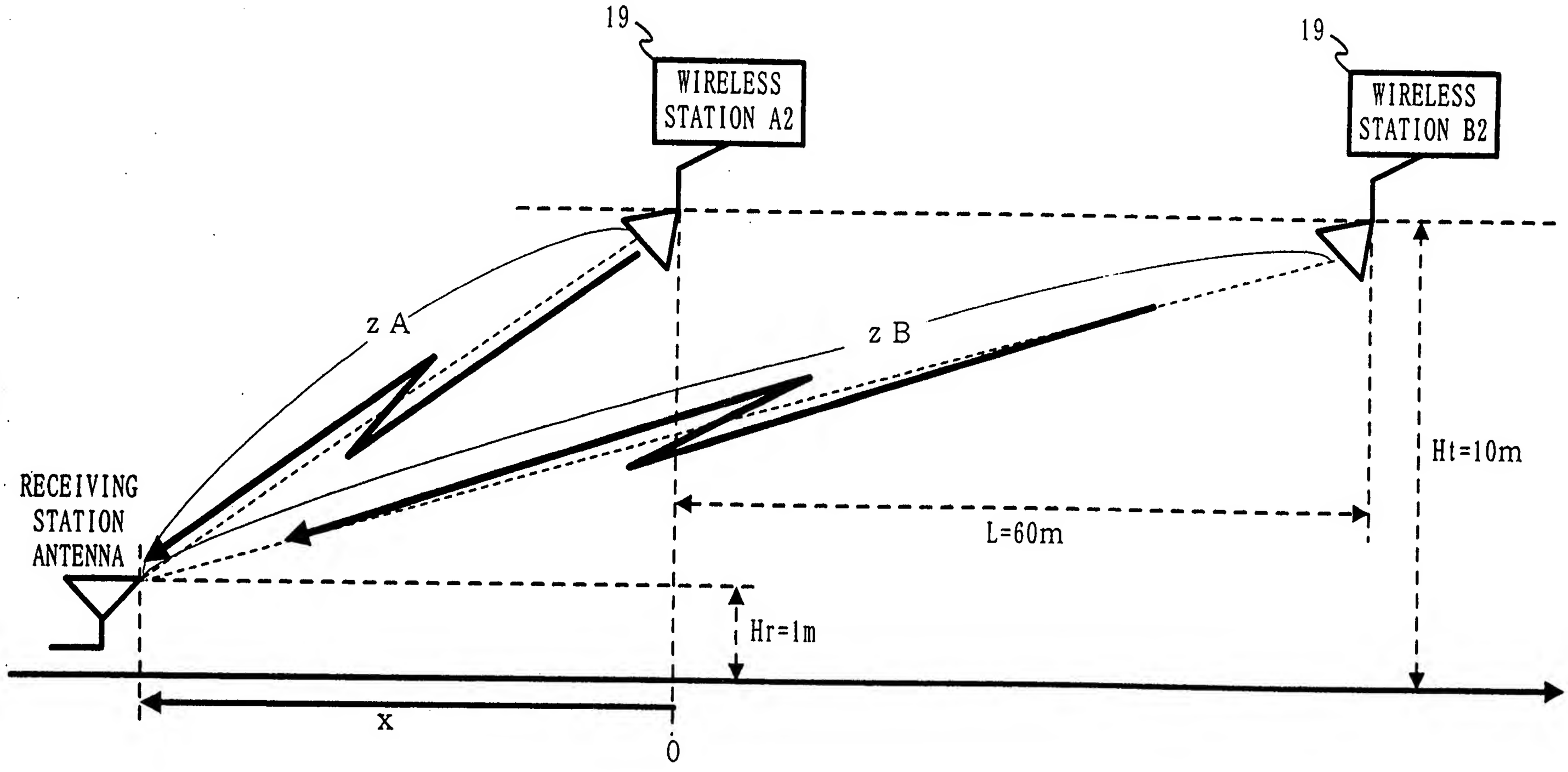
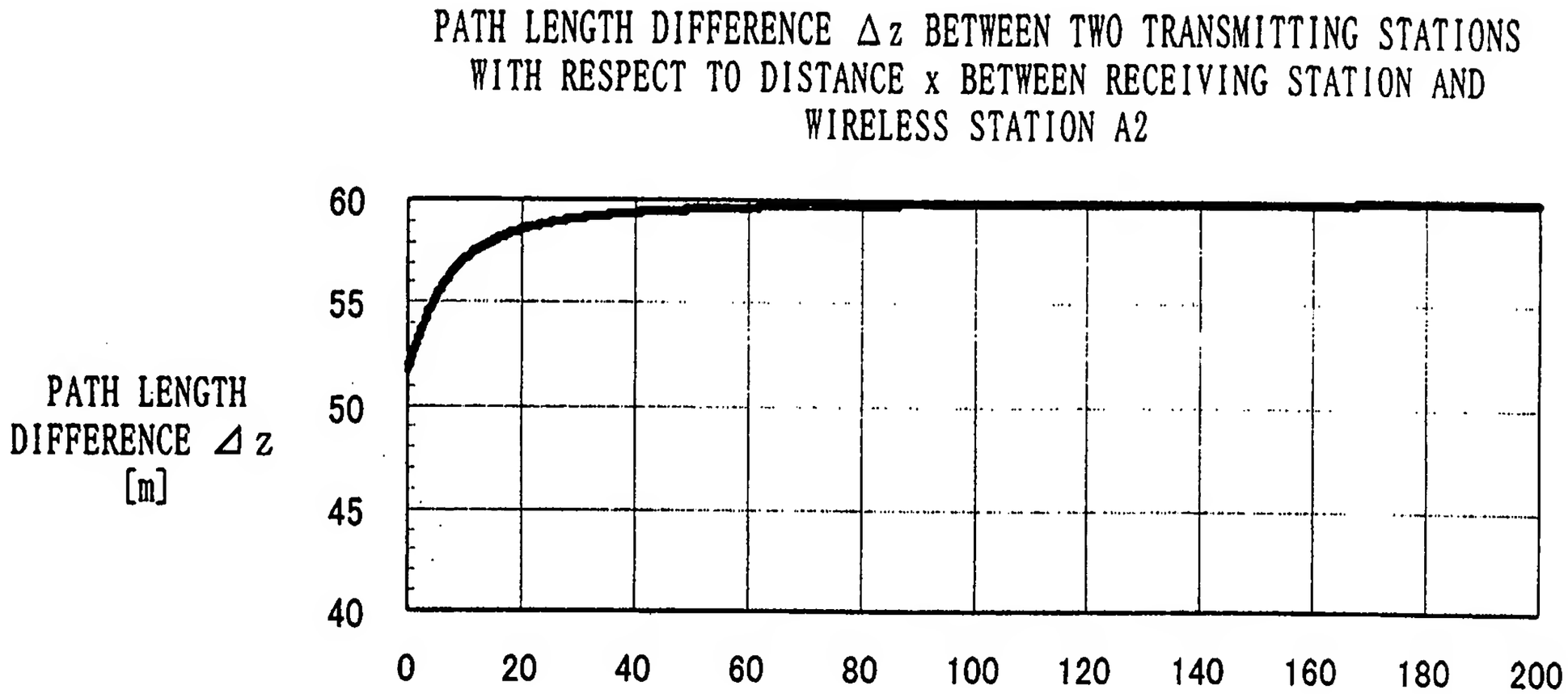

19
WIRELESS STATION A2
19
WIRELESS STATION B2
z A
z B
RECEIVING STATION ANTENNA
Ht=10m
L=60m
Hr=1m
x
0

FIG. 34


PATH LENGTH DIFFERENCE Δz BETWEEN TWO TRANSMITTING STATIONS WITH RESPECT TO DISTANCE x BETWEEN RECEIVING STATION AND WIRELESS STATION A2
PATH LENGTH DIFFERENCE Δz [m]
60
55
50
45
40
0
20
40
60
80
100
120
140
160
180
200
DISTANCE x BETWEEN RECEIVING STATION AND WIRELESS STATION A2 [m]

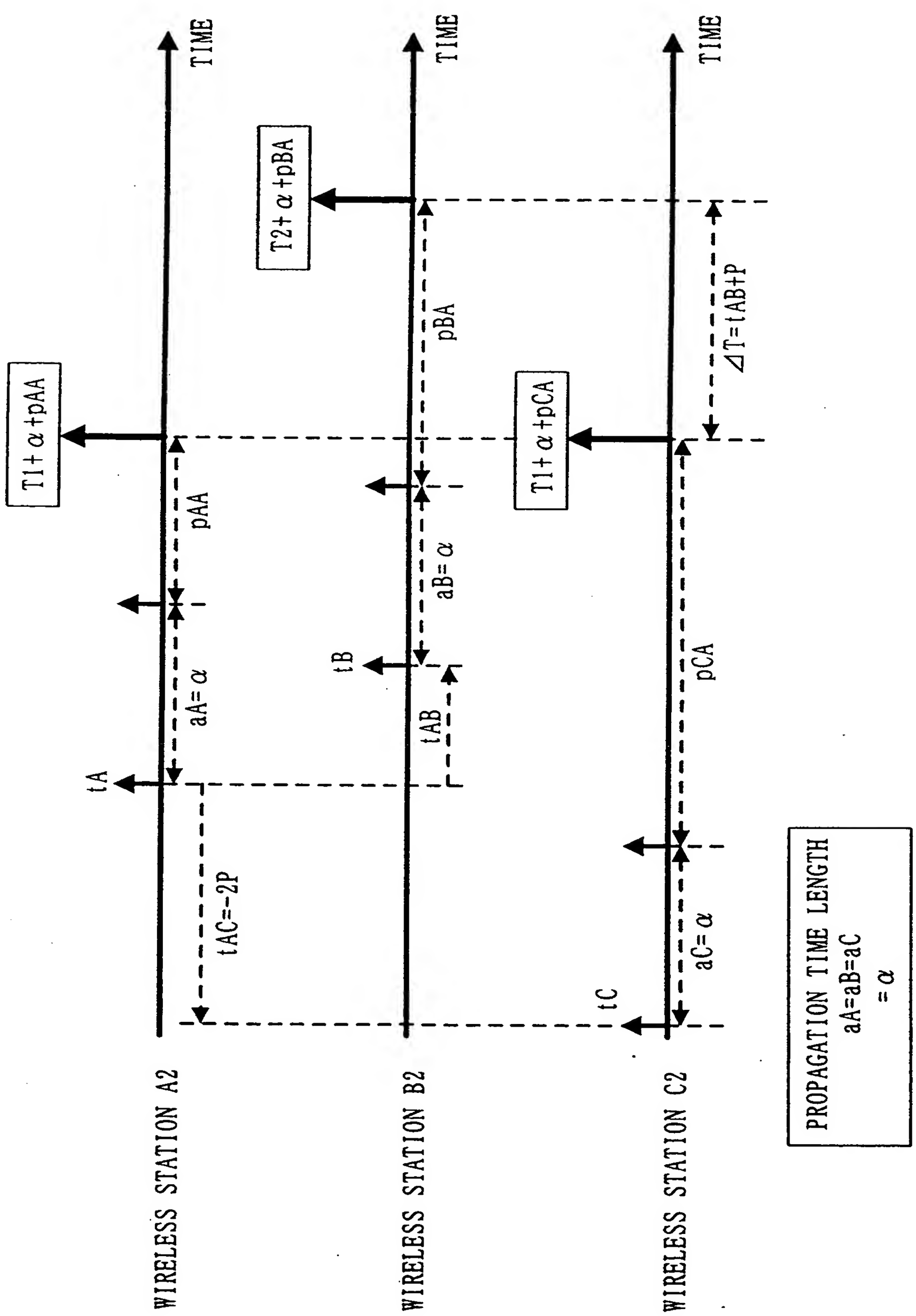

WIRELESS STATION A2
WIRELESS STATION B2
WIRELESS STATION C2
TIME
TIME
TIME
T1+α+pAA
T2+α+pBA
T1+α+pCA
pAA
pBA
pCA
aA=α
aB=α
aC=α
tA
tB
tC
tAB
tAC=-2P
ΔT=tAB+P
PROPAGATION TIME LENGTH
aA=aB=aC
=α

FIG. 35

FIG. 36

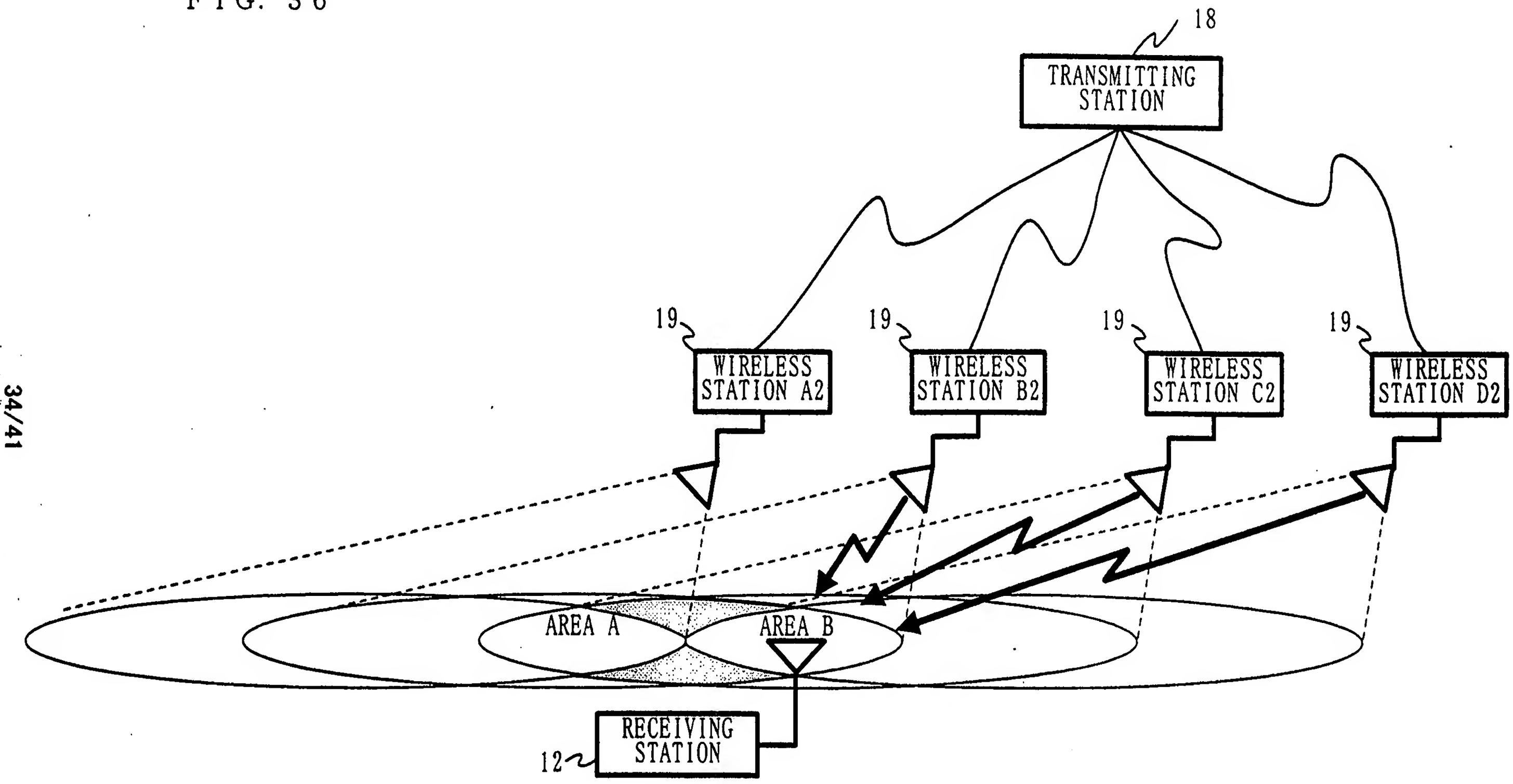

18
TRANSMITTING STATION
19
WIRELESS STATION A2
19
WIRELESS STATION B2
19
WIRELESS STATION C2
19
WIRELESS STATION D2
AREA A
AREA B
12
RECEIVING STATION

FIG. 37

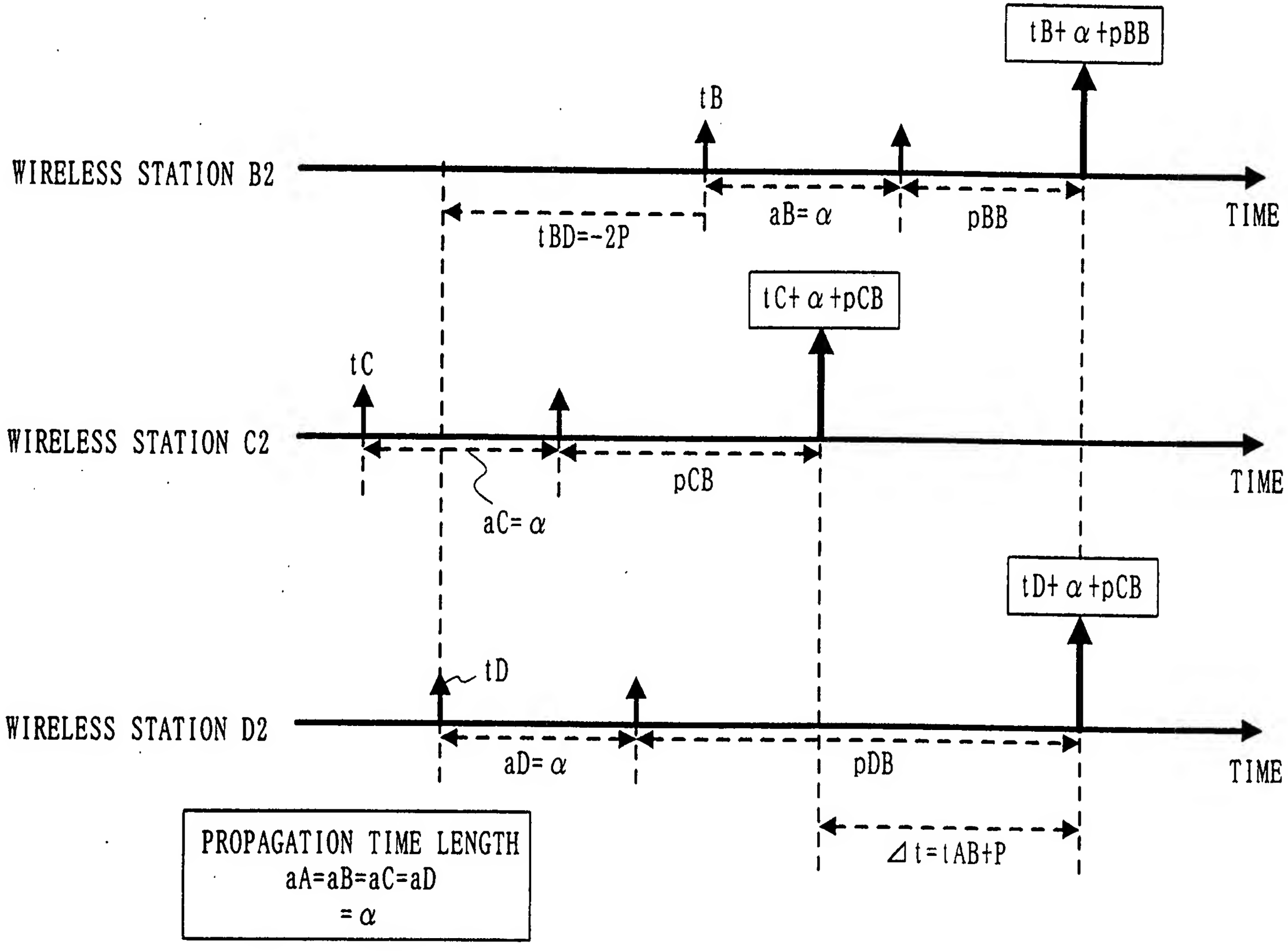
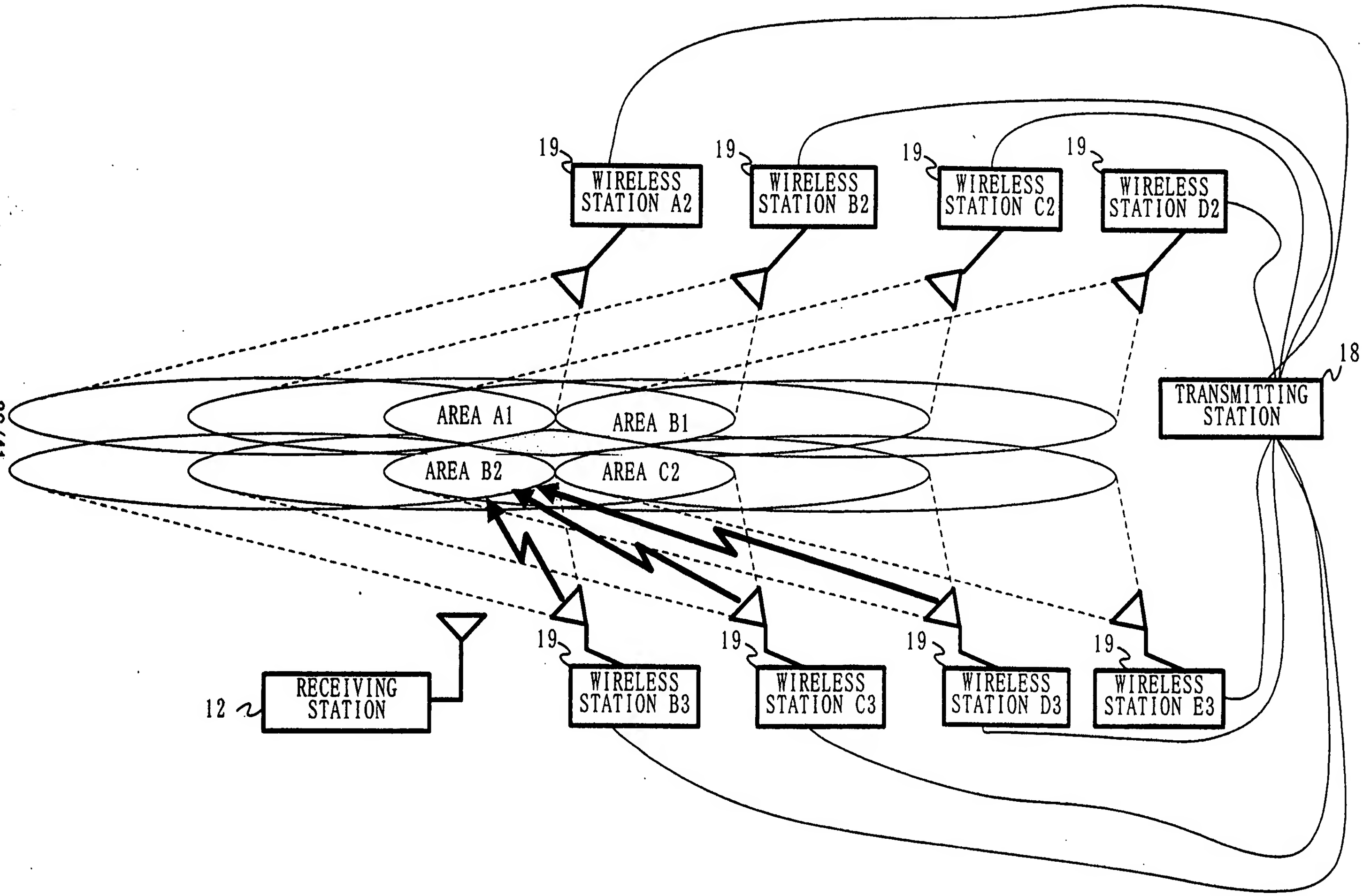

tB+ α +pBB
tB
WIRELESS STATION B2
aB= α
pBB
TIME
tBD=-2P
tC+ α +pCB
tC
WIRELESS STATION C2
pCB
TIME
aC= α
tD+ α +pCB
tD
WIRELESS STATION D2
aD= α
pDB
TIME
Δ t=tAB+P
PROPAGATION TIME LENGTH
aA=aB=aC=aD
= α

FIG. 38


19
WIRELESS STATION A2
19
WIRELESS STATION B2
19
WIRELESS STATION C2
19
WIRELESS STATION D2
18
TRANSMITTING STATION
AREA A1
AREA B1
AREA B2
AREA C2
12
RECEIVING STATION
19
WIRELESS STATION B3
19
WIRELESS STATION C3
19
WIRELESS STATION D3
19
WIRELESS STATION E3

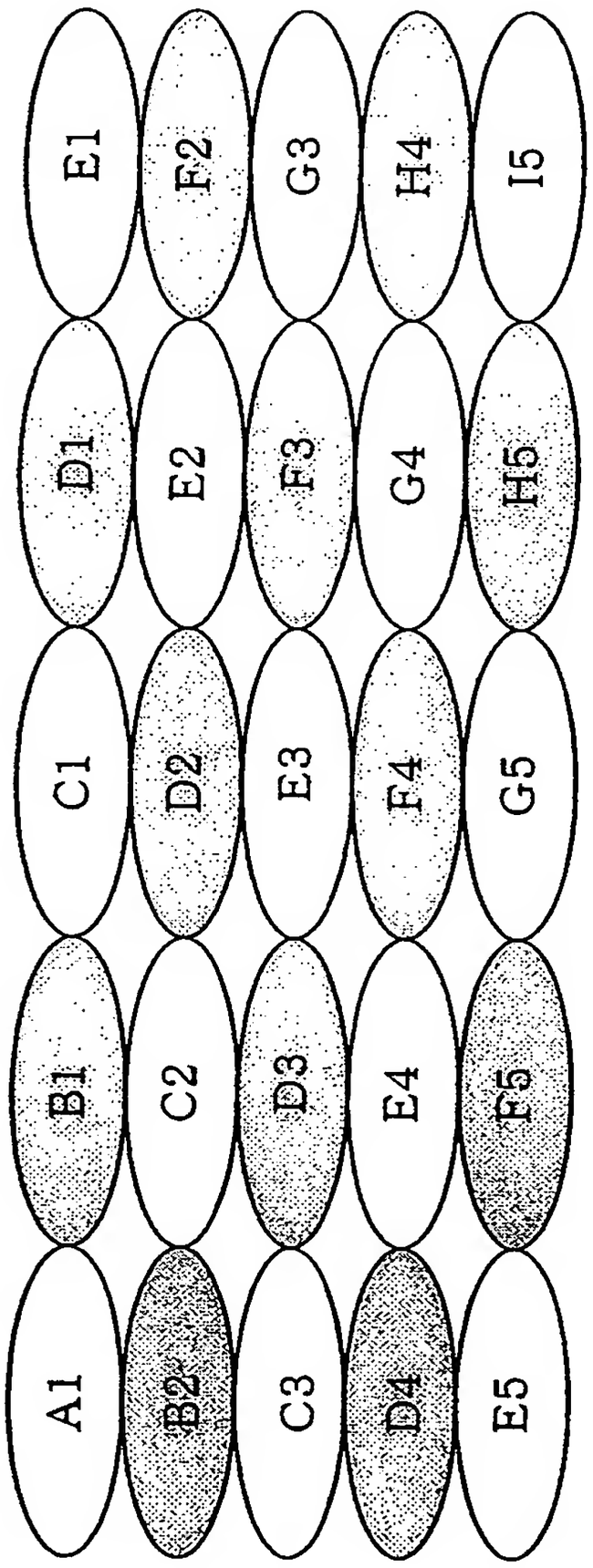
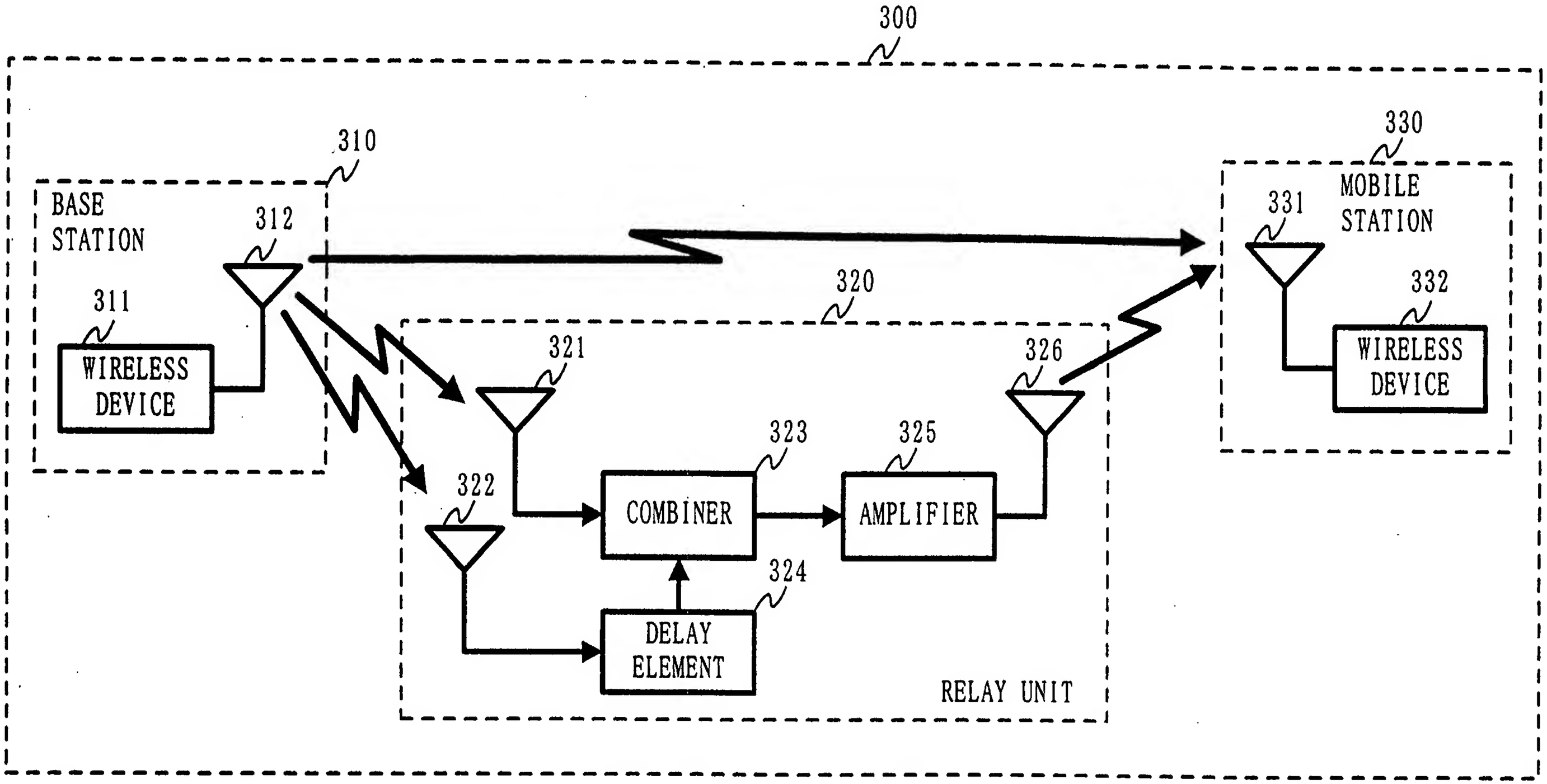

A1
B1
C1
D1
E1
B2
C2
D2
E2
F2
C3
D3
E3
F3
G3
D4
E4
F4
G4
H4
E5
F5
G5
H5
I5

FIG. 39

FIG. 40


300
310
BASE STATION
312
311
WIRELESS DEVICE
320
321
322
323
325
326
COMBINER
AMPLIFIER
324
DELAY ELEMENT
RELAY UNIT
330
MOBILE STATION
331
332
WIRELESS DEVICE

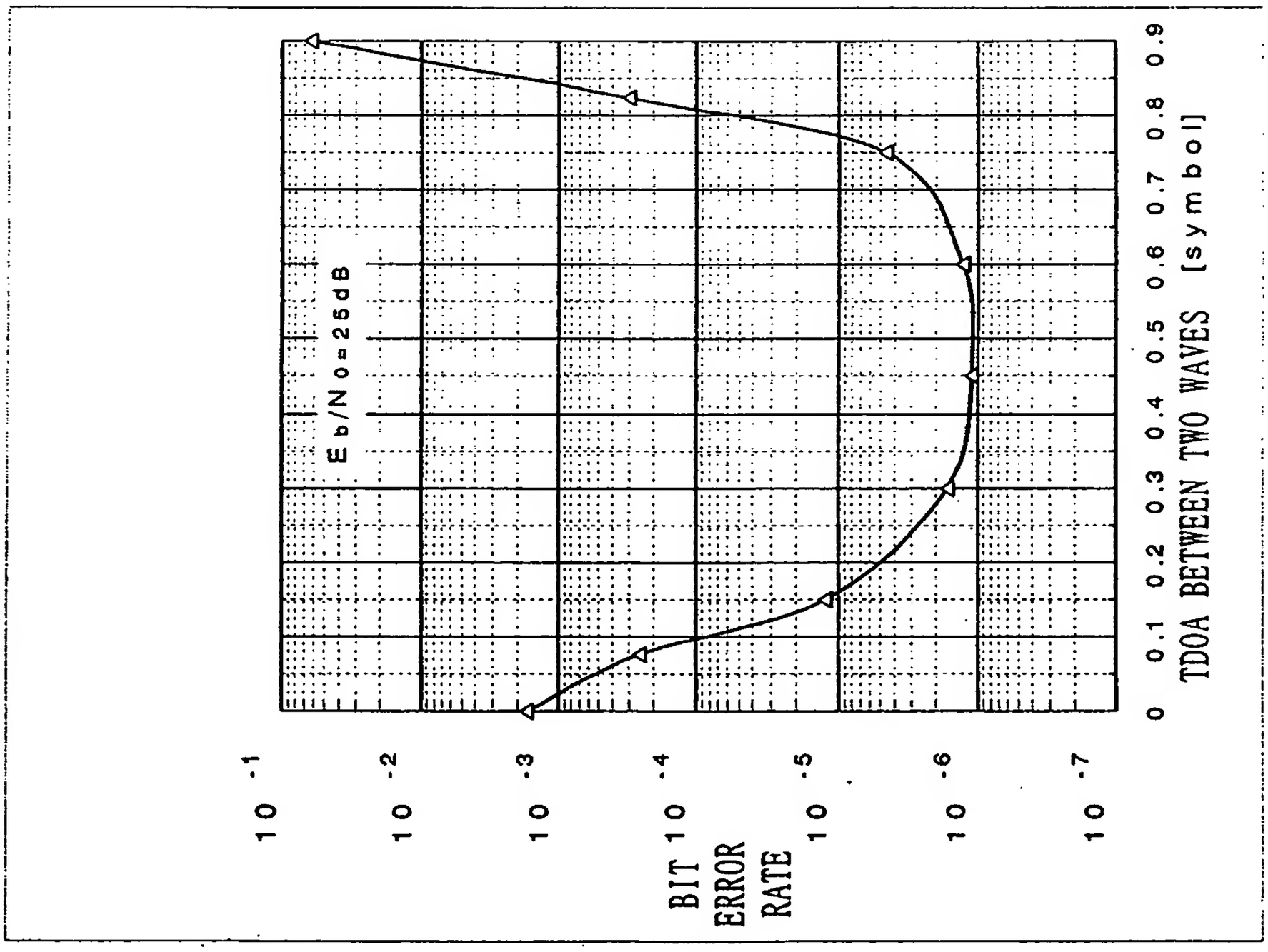

BIT ERROR RATE
10 -1
10 -2
10 -3
10 -4
10 -5
10 -6
10 -7
TDOA BETWEEN TWO WAVES [symbol]
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Eb/No=25dB

FIG. 41

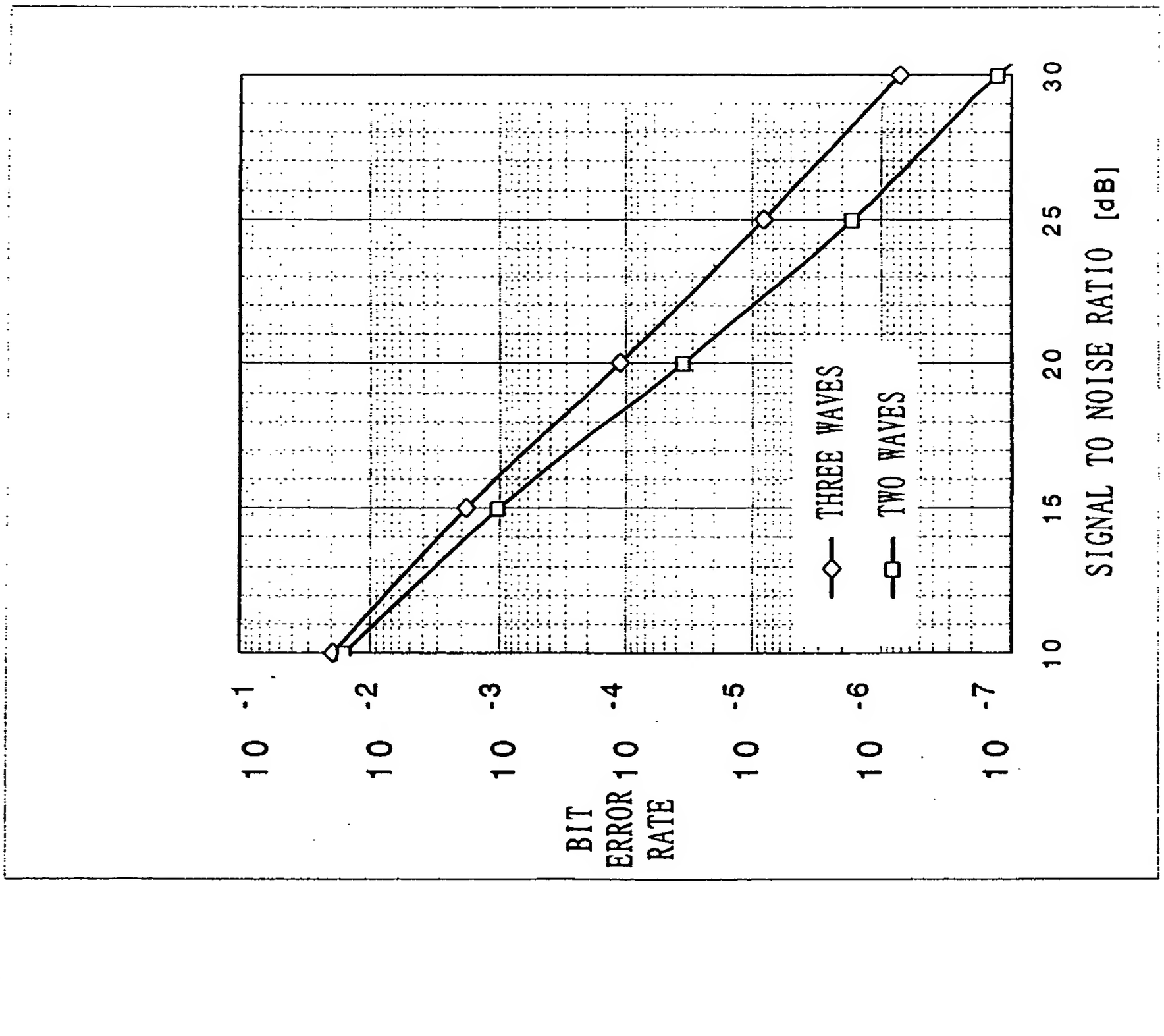

BIT ERROR RATE
10 -1
10 -2
10 -3
10 -4
10 -5
10 -6
10 -7
10
15
20
25
30
SIGNAL TO NOISE RATIO [dB]
THREE WAVES
TWO WAVES

FIG. 42

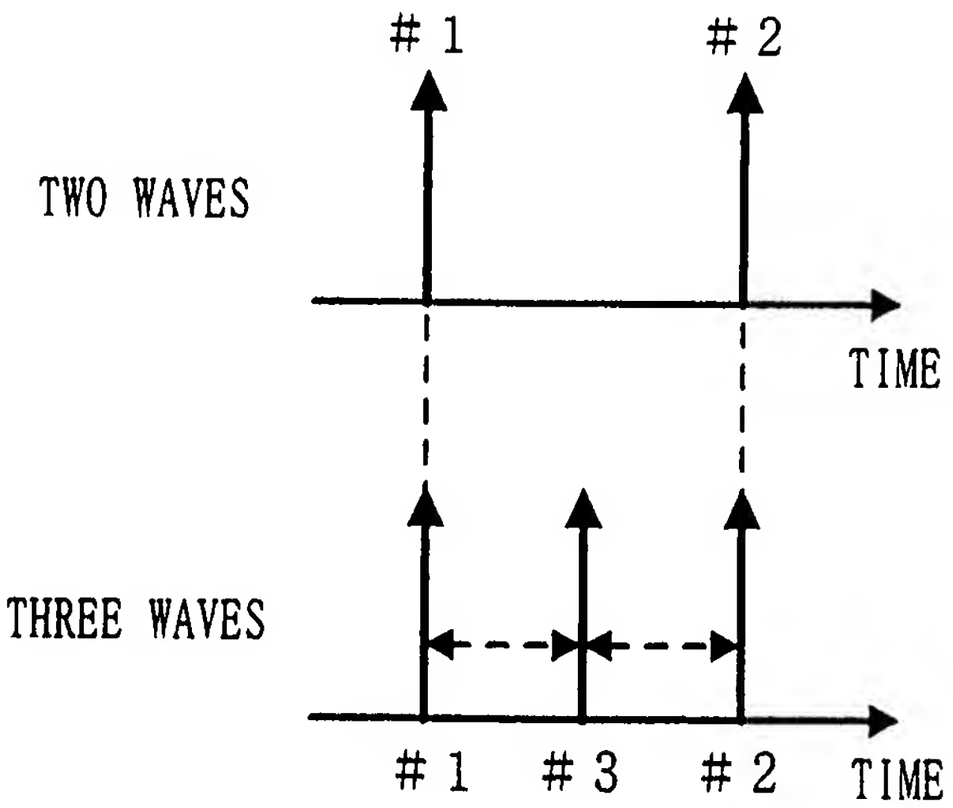



FIG. 43